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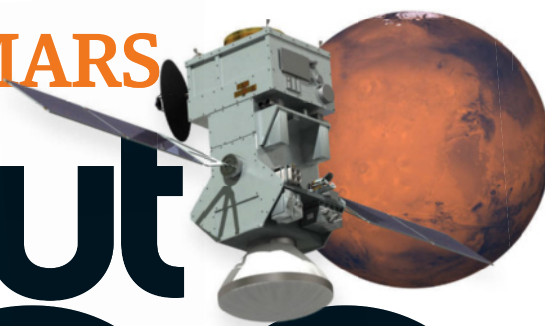

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How well do we know our Sun? According to recent discoveries, we've only scratched the surface

Discover the wonders of the universe

I have a question for you: how well do you know our Sun? I bet you think you know it very well and, since it's so close to us, it's quite an easy to claim to make. It's a given, that in comparison to other stars in the galaxy, we are more familiar with this main sequence star (and others of a similar type!) thanks to its proximity.

However, with the likes of the Sun-staring NASA missions STEREO and SOHO vigilantly watching its ever-changing surface for the past few decades, our Sun has thrown up some pieces of information that have knocked us for six – especially recently. Our feature, 'Think you know our Sun?' is jam-packed with up-to-date information that has even left scientists questioning how well we really know our nearest star.

This issue, we're going all out on mind-boggling facts about our universe and the objects within it. Many of you know that we're on a collision course with the Andromeda Galaxy, some four billion years from now, but did you know that your television is picking up the relic radiation – known as the Cosmic Microwave Background – that came from the Big Bang? **All About Space** presents some out-of-this-world facts about the cosmos this month. We also get up close to the alien worlds that may in fact provide a snapshot into the future of our very own planet: the super-Venus.

Elsewhere in the issue, if you've got the astro-bug after watching *Stargazing Live*, astronomer Mark Thompson has some handy tips for you to get started in stargazing, while we provide a complete guide to this month's night sky and tutorials to coincide with the best astronomical events in February and early March.

Gemma Lavender
Deputy Editor

Contributors

Jonathan O'Callaghan

■ Peering into the atmosphere of a super-Venus this month, Jonathan discovers that these very hot alien worlds provide a snapshot into Earth's future.

Colin Stuart

■ The universe is an incredibly violent place as Colin reveals this issue. You wouldn't want to be in the vicinity of the most aggressive members of the cosmos.

David Crookes

■ We can guarantee you'll find out something you didn't know about our own Sun this month. David has the details on page 16.

Laura Mears

■ Laura brings us the most mind-boggling facts about space, which are sure to leave you amazed about our universe.

> "If we don't try to understand the star on our doorstep, we have no hope of understanding others in the universe"
>
> **Dr Scott McIntosh, solar physicist [page 16]**

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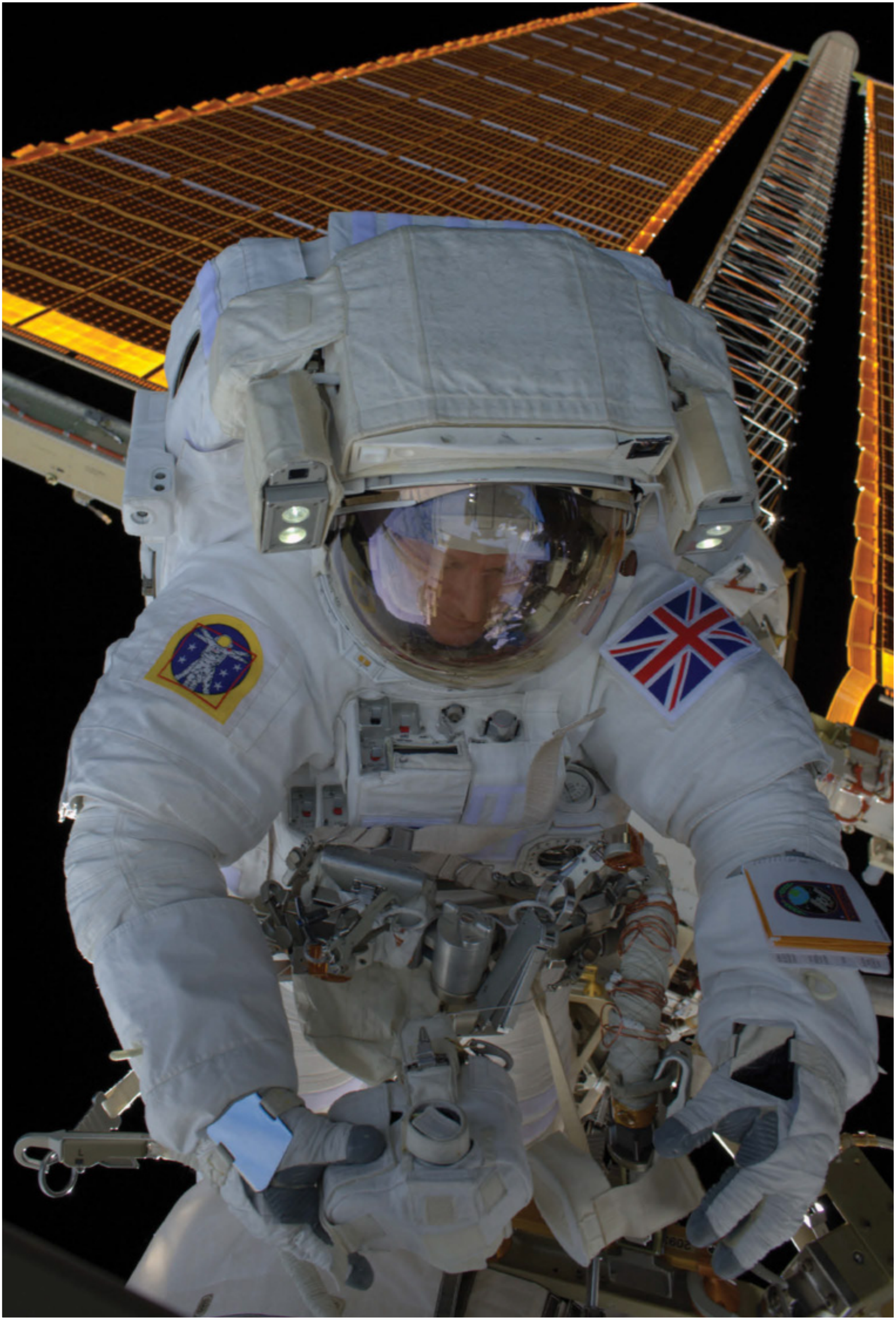
YOUR FIRST CONTACT WITH THE UNIVERSE

Major Tim takes a spacewalk selfie

Tim Peake was sent to the International Space Station (ISS) on 15 December 2015 and has already taken part in a spacewalk with fellow astronaut Tim Kopra of NASA. This was to carry out repairs and replace a malfunctioning voltage regulator on the outside of the ISS, which maintains its orbit with an altitude of around 400 kilometres (250 miles) above Earth's surface. Successfully replacing the faulty unit ahead of schedule, Peake took the opportunity to take a selfie before the spacewalk was cut short when Kopra's helmet sprung a water leak!



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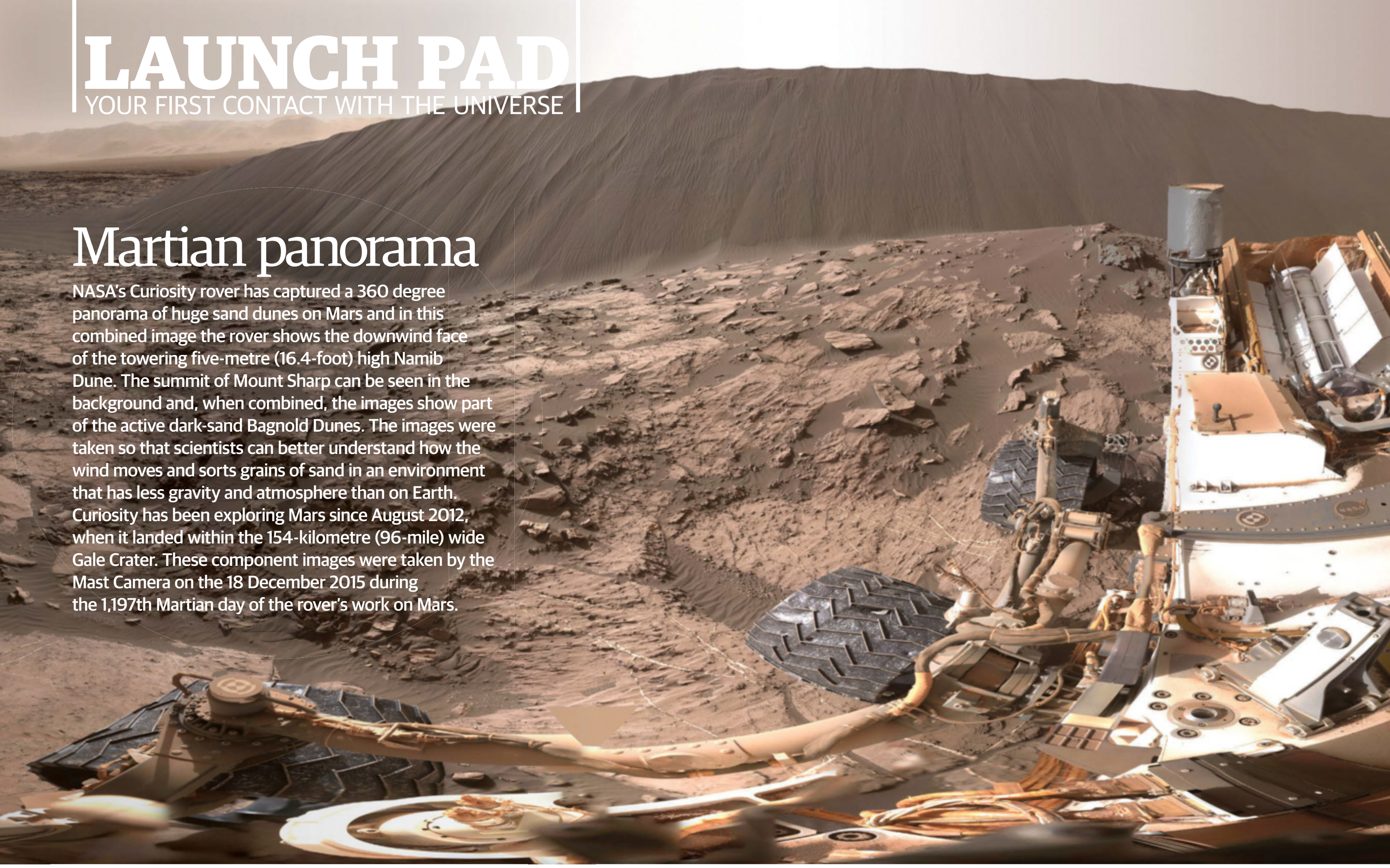
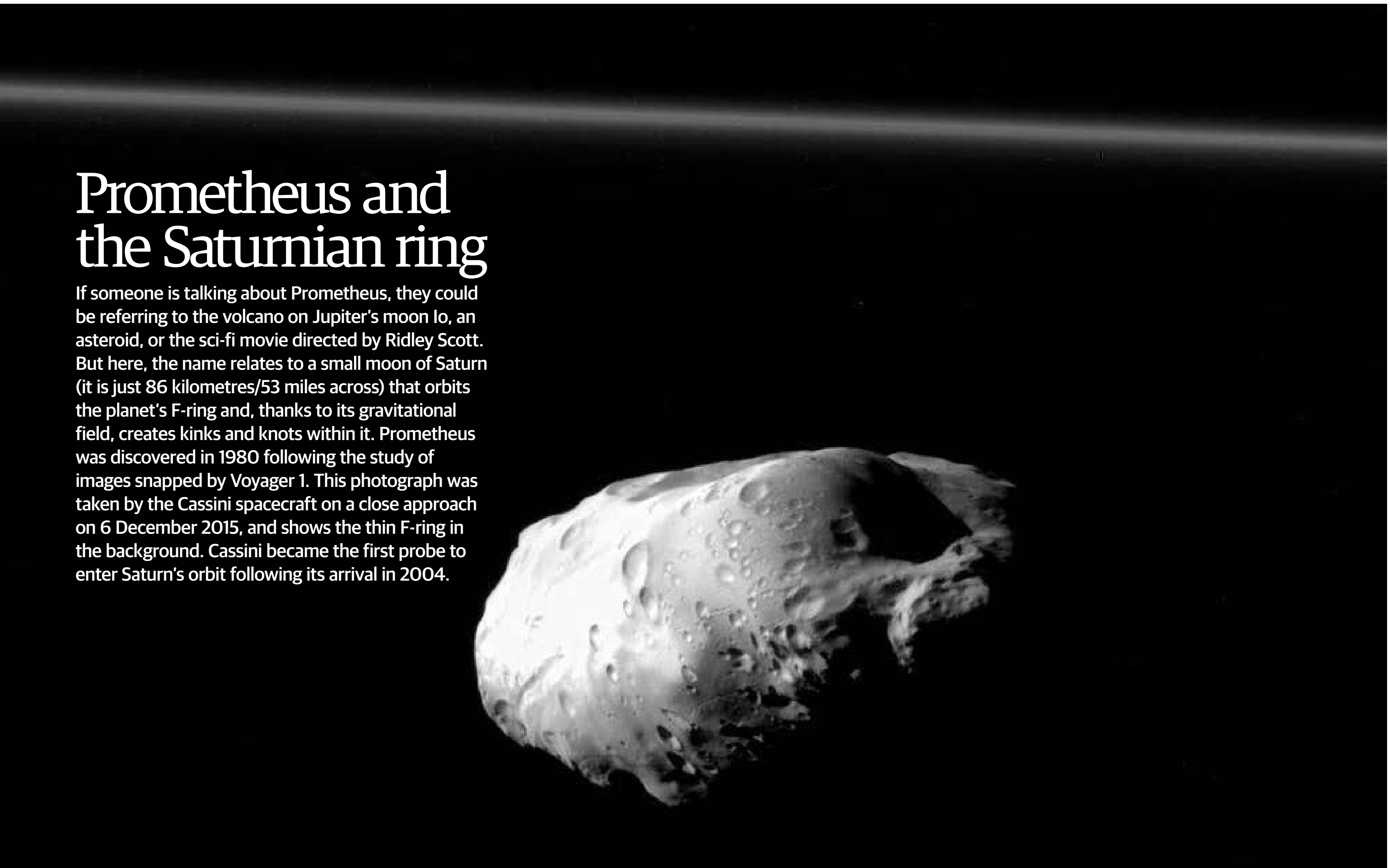


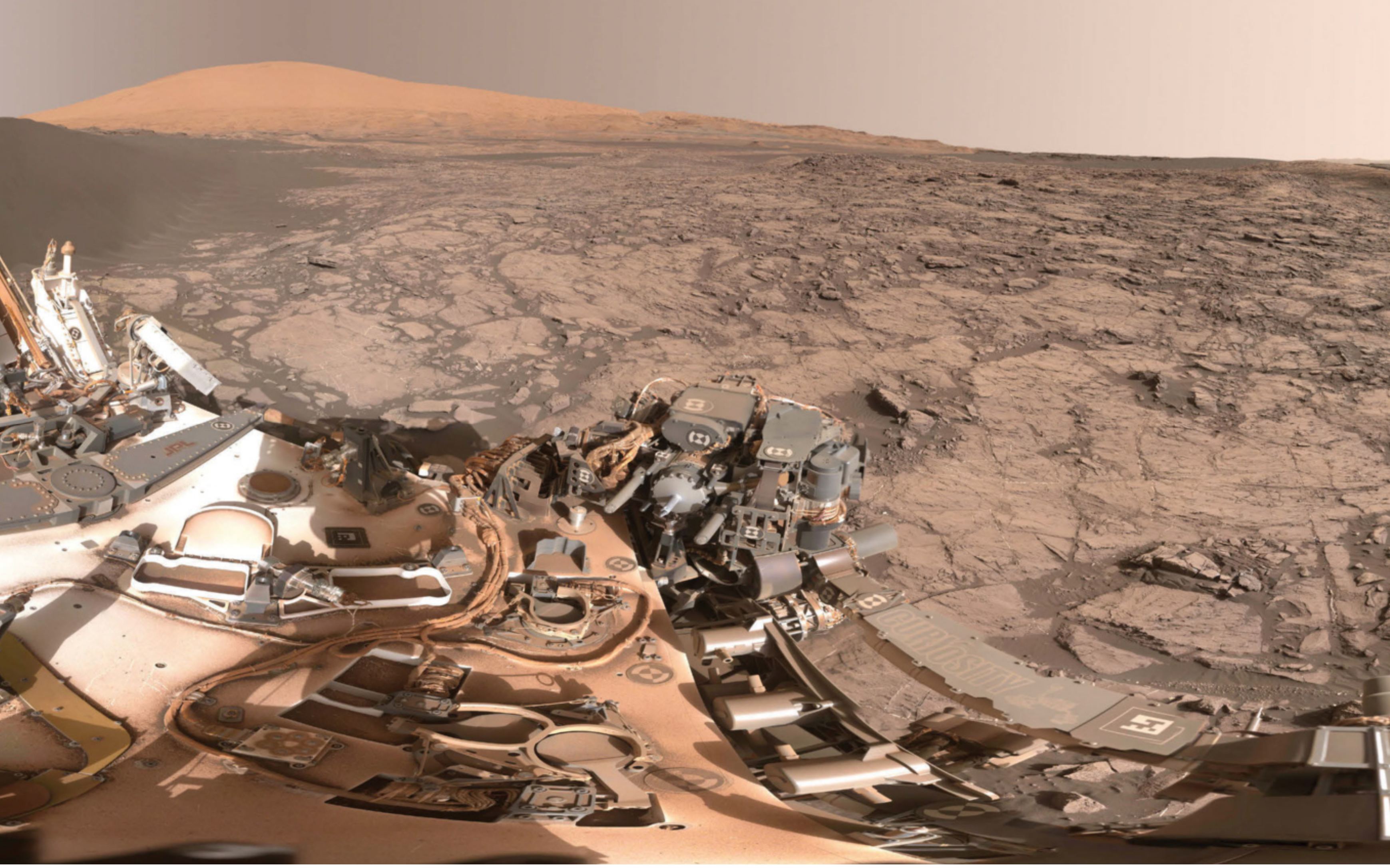
Martian panorama

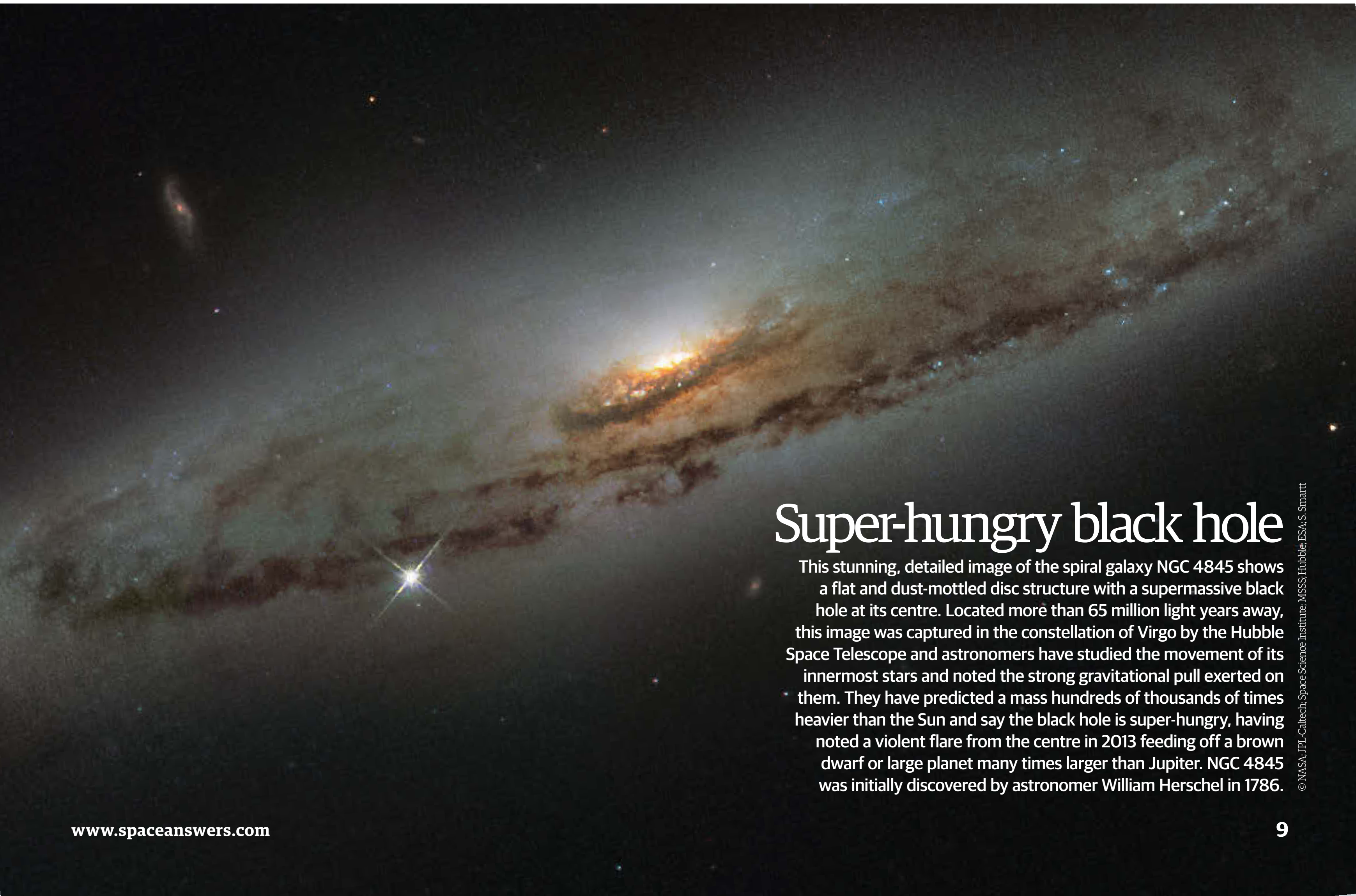
NASA's Curiosity rover has captured a 360 degree panorama of huge sand dunes on Mars and in this combined image the rover shows the downwind face of the towering five-metre (16.4-foot) high Namib Dune. The summit of Mount Sharp can be seen in the background and, when combined, the images show part of the active dark-sand Bagnold Dunes. The images were taken so that scientists can better understand how the wind moves and sorts grains of sand in an environment that has less gravity and atmosphere than on Earth. Curiosity has been exploring Mars since August 2012, when it landed within the 154-kilometre (96-mile) wide Gale Crater. These component images were taken by the Mast Camera on the 18 December 2015 during the 1,197th Martian day of the rover's work on Mars.



Prometheus and the Saturnian ring

If someone is talking about Prometheus, they could be referring to the volcano on Jupiter's moon Io, an asteroid, or the sci-fi movie directed by Ridley Scott. But here, the name relates to a small moon of Saturn (it is just 86 kilometres/53 miles across) that orbits the planet's F-ring and, thanks to its gravitational field, creates kinks and knots within it. Prometheus was discovered in 1980 following the study of images snapped by Voyager 1. This photograph was taken by the Cassini spacecraft on a close approach on 6 December 2015, and shows the thin F-ring in the background. Cassini became the first probe to enter Saturn's orbit following its arrival in 2004.





Super-hungry black hole

This stunning, detailed image of the spiral galaxy NGC 4845 shows a flat and dust-mottled disc structure with a supermassive black hole at its centre. Located more than 65 million light years away, this image was captured in the constellation of Virgo by the Hubble Space Telescope and astronomers have studied the movement of its innermost stars and noted the strong gravitational pull exerted on them. They have predicted a mass hundreds of thousands of times heavier than the Sun and say the black hole is super-hungry, having noted a violent flare from the centre in 2013 feeding off a brown dwarf or large planet many times larger than Jupiter. NGC 4845 was initially discovered by astronomer William Herschel in 1786.

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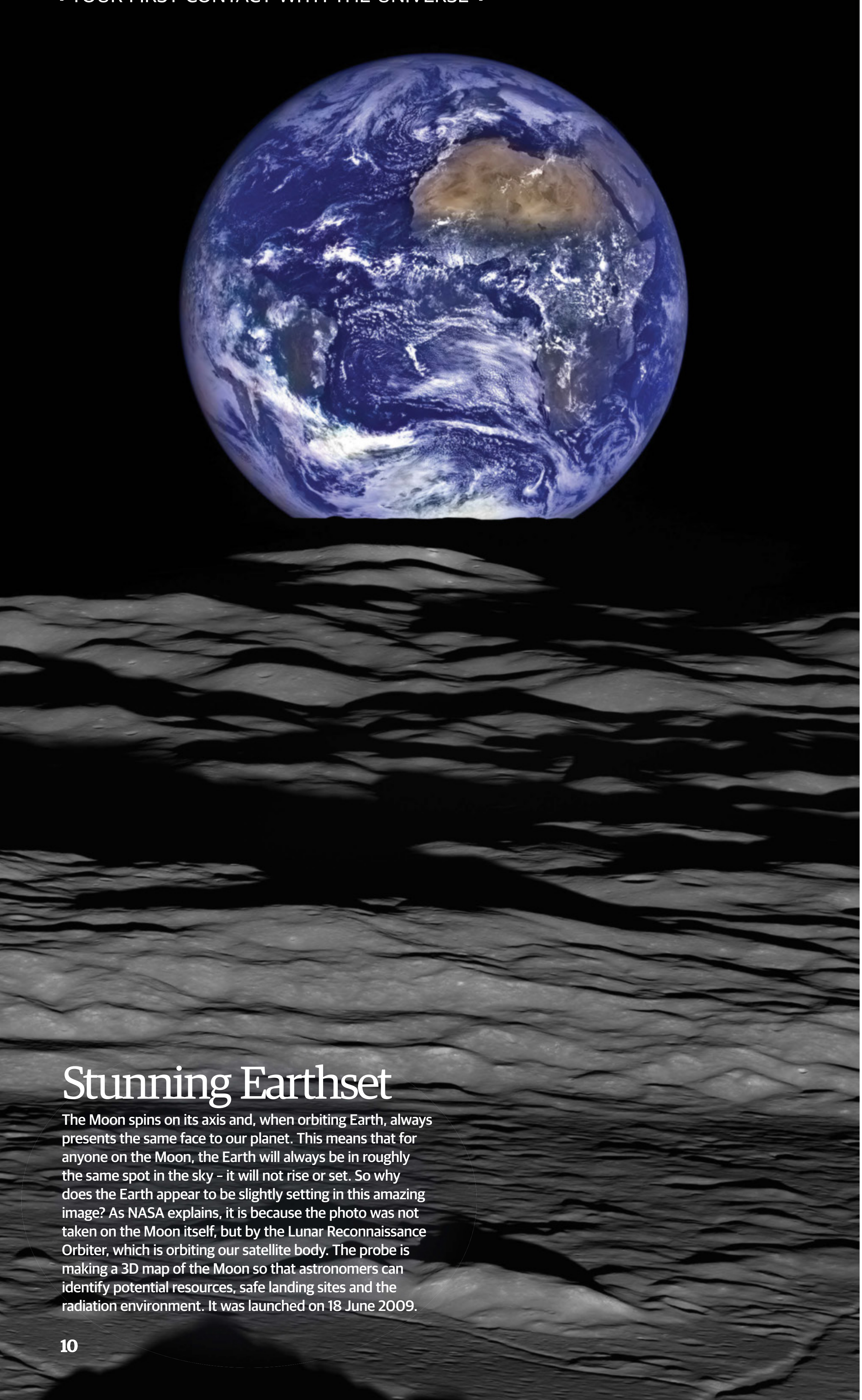
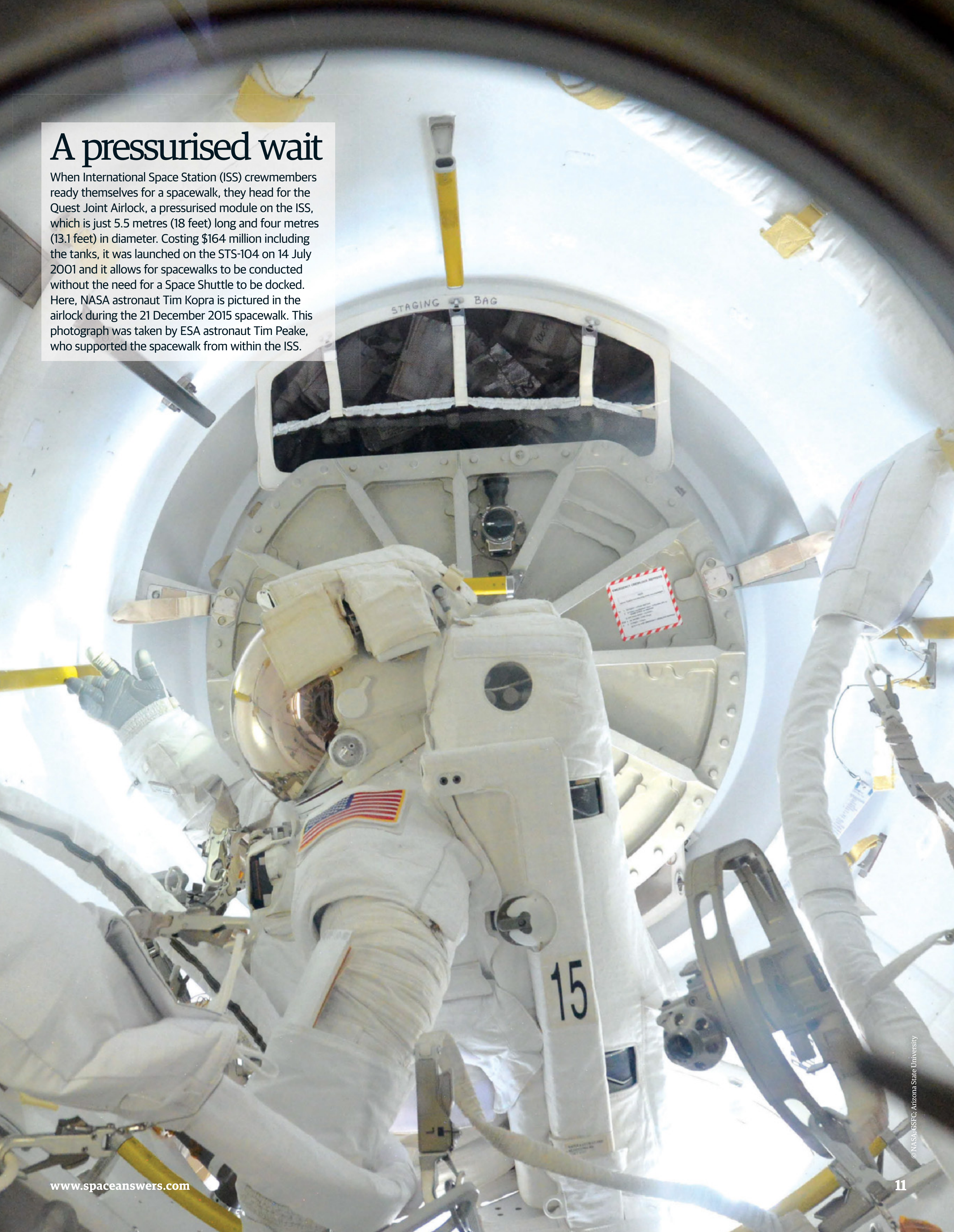


Stunning Earthset

The Moon spins on its axis and, when orbiting Earth, always presents the same face to our planet. This means that for anyone on the Moon, the Earth will always be in roughly the same spot in the sky – it will not rise or set. So why does the Earth appear to be slightly setting in this amazing image? As NASA explains, it is because the photo was not taken on the Moon itself, but by the Lunar Reconnaissance Orbiter, which is orbiting our satellite body. The probe is making a 3D map of the Moon so that astronomers can identify potential resources, safe landing sites and the radiation environment. It was launched on 18 June 2009.

A pressurised wait

When International Space Station (ISS) crewmembers ready themselves for a spacewalk, they head for the Quest Joint Airlock, a pressurised module on the ISS, which is just 5.5 metres (18 feet) long and four metres (13.1 feet) in diameter. Costing $164 million including the tanks, it was launched on the STS-104 on 14 July 2001 and it allows for spacewalks to be conducted without the need for a Space Shuttle to be docked. Here, NASA astronaut Tim Kopra is pictured in the airlock during the 21 December 2015 spacewalk. This photograph was taken by ESA astronaut Tim Peake, who supported the spacewalk from within the ISS.



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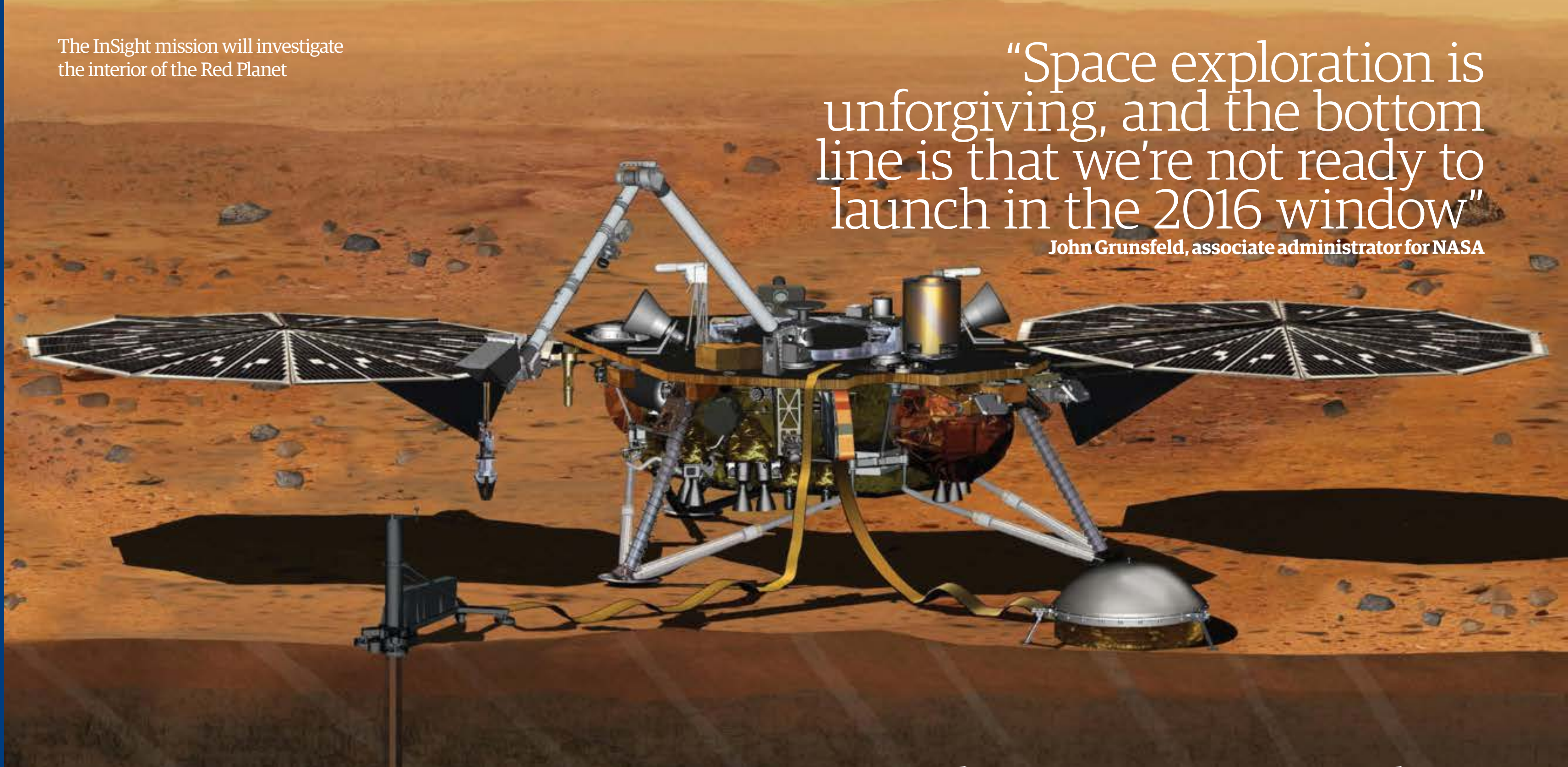


The InSight mission will investigate the interior of the Red Planet

> "Space exploration is unforgiving, and the bottom line is that we're not ready to launch in the 2016 window"
> **John Grunsfeld, associate administrator for NASA**

NASA suspends March launch of InSight mission to Mars

Following unsuccessful attempts to fix a leak in its science payload, the agency has confirmed the programme won't make its 2016 launch window

NASA has announced that the Mars-bound InSight (Interior Exploration using Seismic Investigations Geodesy and Heat Transport) vehicle will not launch for the Red Planet this year, following numerous failed attempts to fix a leak in the prime instrument of its science payload.

"Learning about Mars' interior structure has been a high priority objective for planetary scientists since the Viking era," says John Grunsfeld, associate administrator for NASA's Science Mission Directorate in Washington, in an official statement. "We push the boundaries of space technology with our missions to enable science, but space exploration is unforgiving, and the bottom line is that we're not ready to launch in the 2016 window. A decision on a path going forward will be made in the coming months, but one thing is clear: NASA remains fully committed to the scientific discovery and exploration of Mars."

The instrument at the heart of the issue is the Seismic Experiment for Interior Structure (SEIS), a bespoke seismometer designed and built by France's Centre National d'Études Spatiales (CNES). The tool is used to measure minute ground movements, but an issue with the vacuum seal around its three primary sensors has forced the whole mission into delay. Considering the harsh environments the vehicle would have to endure on Mars, NASA has to be 100 per cent confident that even the smallest component is up to task.

"It's the first time ever that such a sensitive instrument has been built. We were very close to succeeding, but an anomaly has occurred, which requires further investigation. Our teams will find a solution to fix it, but it won't be solved in time for a 2016 launch," says Marc Pircher, director of CNES's Toulouse Space Centre. Despite this recent setback with InSight, NASA is still making progress with its ambitious plans for Mars - including its designs to take a manned mission to the Red Planet aboard the still-in-development Space Launch System.

"InSight's investigation of the Red Planet's interior is designed to increase understanding of how all rocky planets, including Earth, formed and evolved," adds Bruce Banerdt, InSight principal investigator at NASA's Jet Propulsion Laboratory, California. "Mars retains evidence about the early development of the rocky planets that has been erased on Earth by internal churning. Gaining information about the core, mantle and crust of Mars is a high priority for planetary science, and InSight was built to accomplish this."

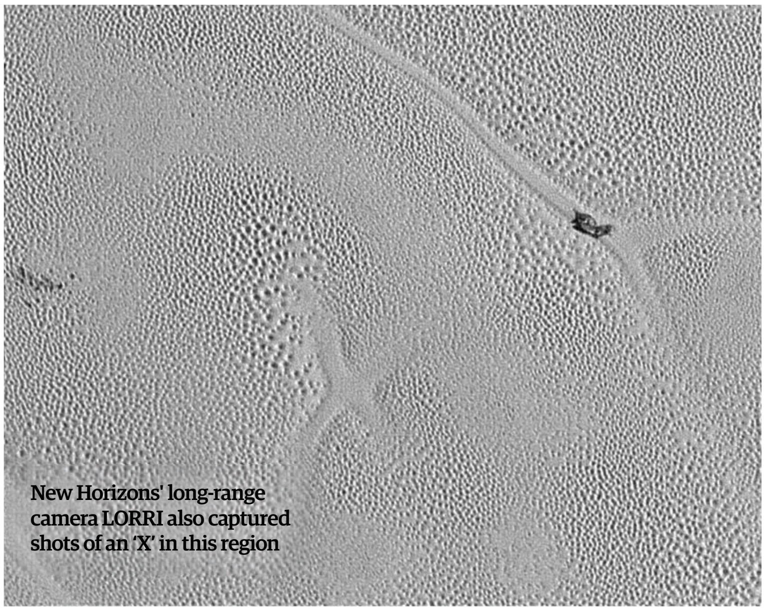
New Horizons captures curious activity on Pluto's frozen face

Unusual cellular movement at the icy Sputnik Planum has scientists at NASA scratching their heads

A new image that was captured by NASA's New Horizons' Long Range Reconnaissance Imager (LORRI) on Christmas Eve has piqued the interest of scientists due to the strange fragmentation of ice at the Sputnik Planum – a large frozen plain that forms the left side of Pluto's 'heart'.

The Sputnik Planum, which sits at a lower elevation than the surrounding regions, has seemingly divided itself into separate cells, with each of these sections ranging between 16 and 40 kilometres (10 and 25 miles) in diameter. Odder still, when viewed at low Sun angles, it appears that these cells have slightly elevated centres as well as raised margins. So far, NASA has calculated a height differentiation of around 100 metres (328 feet) or so at these borders.

So what's caused this bitterly cold region of Pluto to subdivide so definitively? Missions scientists at NASA have a few theories, the chief one being that these cells were caused by the slow thermal convection of the nitrogen-filled ices that populate the Sputnik Planum. The natural heat bubbling up from Pluto's core is gradually warming the solid nitrogen beneath the Planum, which is causing sections to shift and bob to the surface before freezing again into place, restarting the cycle all over again.


New Horizons' long-range camera LORRI also captured shots of an 'X' in this region

"This part of Pluto is acting like a lava lamp," comments William McKinnon, deputy lead scientist of the New Horizons Geology, Geophysics and Imaging team, from Washington University in St. Louis. "That is, if you can imagine a lava lamp as wide as, and even deeper than, Hudson Bay."

A 3D simulation based on New Horizons' data that was collected from the region has led the space agency to conclude that this process has seen the solid nitrogen evolve for millions of years, creating an ever-changing map of shifting borders and cells. ■

Early universe's heaviest galaxy cluster found

NASA's Great Observatories are probing a cluster that weighs 500 trillion Suns

Three of NASA's Great Observatories are performing the most detailed study yet of an extremely large and relatively new galaxy cluster located 10 billion light years from Earth. The galaxy cluster, classified as IDCS J1426.5+3508 (or IDCS 1426 for short), weighs the equivalent of 500 trillion Suns and is the youngest cluster on record to ever reach such a size at such a young age. First discovered in 2012 by the Spitzer Space Telescope, IDCS 1426 is confirmed as 90 per cent dark matter (thanks to data from the Chandra X-Ray), adding a fascinating aspect to this giant object.

Galaxy cluster IDCS 1426 is being observed from when the universe was only 3.8 billion years old

"We are pushing the boundaries with this discovery," says Mark Brodwin, lead scientist at the University of Missouri. "As one of the earliest massive structures to form in the universe, it sets a high bar for theories attempting to explain how clusters and galaxies evolve." The Chandra data also reveals a misaligned nest of X-rays near the heart of the cluster, which suggests a past merger with another developing cluster in the last 500 million years. "Mergers with other galaxy clusters should have been more common in the early universe," adds coauthor Michael McDonald of the Massachusetts Institute of Technology. "That appears to have played an important part in this young cluster's rapid formation." ■

Space News in Brief

Superstars discovered by NASA telescopes

Scientists, using archival data from NASA's Spitzer and Hubble Space Telescopes, have discovered five colossal objects similar in size and composition to supersized stellar system, Eta Carinae. If these objects share its characteristics, it could provide new opportunities to study these celestial factories of energy.

Rogue stars trail heat waves

Images captured from NASA's Spitzer Space Telescope and Wide-field Infrared Survey Explorer (WISE) have determined that fast moving stars actively pile up material in front of them, much like water swells around the bow of a ship. These 'bow shocks' are made up of space dust and other celestial detritus and often leaves a trail of tell-tale infrared waves.

JWST passes crucial radio waves test

The James Webb Space Telescope, which NASA is hoping will replace Hubble as the agency's leading space lens, has just passed a milestone radio wave test to ensure that the electromagnetic craft and its instruments can withstand the radiated battering of life in space. Conducted at NASA's EMI Laboratory at Goddard Space Centre, the test sees JWST one step closer to launch.

Milky Way age map reveals growth rings

Scientists at the Max Planck Institute for Astronomy have constructed the first age map of the Milky Way. The ground-breaking collection of data shows the gradual expansion and growth of the flattened disc of dust and stars upon which our Solar System's spiral arms are positioned.

LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

More than 13,500 NEOs have been discovered to date, with 95 per cent identified since NASA began conducting surveys in 1998

New asteroid-defense project gets the green light

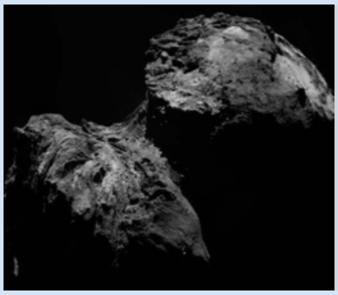
NASA programme finally centralised to prepare for and manage Near-Earth Objects

After much toing and froing, NASA has finally centralised its ongoing programme to prepare for and manage Near-Earth Objects (NEOs) in the form of the Planetary Defense Coordination Office (PDCO). With 1,500 NEOs identified each year, the new department will oversee all programmes and projects related to asteroid and comet detection, as well as organising interagency and intergovernmental responses.

"Asteroid detection, tracking and defence of our planet is something that NASA, its interagency partners, and the global community take very seriously," says John Grunsfeld, associate administrator for NASA's Science Mission Directorate. "While there are no known impact threats at this time, the 2013 Chelyabinsk super-fireball and the recent 'Halloween Asteroid' close approach remind us of why we need to remain vigilant and keep our eyes to the sky."

As well as tracking potential hazards from outer space, the PDCO will also take charge of public warnings and assist the US government and local law enforcement agencies with potential relocation efforts for threats based on solid scientific data. The new formalisation will also see the PDCO working closely with the Federal Emergency Management Agency in designing and preparing planetary defence programmes.

"The formal establishment of the Planetary Defense Coordination Office makes it evident that the agency is committed to perform a leadership role in national and international efforts for detection of these natural impact hazards, and to be engaged in planning if there is a need for planetary defence," adds Lindley Johnson, lead programme executive for the office, with the title of Planetary Defense Officer. ●



The estranged Philae lander has been radio silent for months now

ESA makes last effort to find Philae

Prospects are looking bleaker by the day for the comet-based lander

After months of radio silence, the European Space Agency has made one last ditch effort to locate the Philae lander, using a communications pass by the Rosetta probe. The lander, which travelled to Comet 67P/Churyumov-Gerasimenko with the Rosetta probe, touched down on the comet's surface on 12 November 2014 and, despite a few bounces, the plucky vehicle remained in contact with ESA mission control. But, an unforeseen issue caused the lander to go offline and scientists haven't made contact with it since 9 July last year.

"Time is running out," says Philae landing manager, Stephan Ulamec in a grimly honest post on the ESA's website last month. That short window refers to the increasing distance Comet 67P is travelling away from Earth, as the temperatures will drop beyond Philae's operating levels.

ESA mission command sent a signal to the lander's onboard flywheel in a hope to shake away the build-up of dust and shift its position so that its solar panels can soak up the diminishing rays from the Sun. "There is a small chance," says operations manager Cinzia Fantinati. "We want to leave no stone unturned." ●

Astronauts' biological clocks affected by spaceflight, says NASA research

The rigors of living and operating in space can cause sleep patterns to be disturbed and misaligned over long periods

Astronauts onboard the ISS witness 16 sunsets and sunrises a day, which hugely affects their sleep patterns

A new internal research report at NASA has been investigating the effects of spaceflight on the sleep patterns and biological clocks of astronauts, and early results suggest a number of different factors can significantly misalign those vitally important resting periods.

The report, conducted at NASA's Ames Research Center in Silicon Valley by Fatigue Countermeasures Laboratory researcher Erin Flynn-Evans, has been monitoring a variety of different factors that could potentially disturb the sleep of an astronaut, such as normal operational noise and uncomfortable temperatures. It also highlights the effect these have on their circadian rhythms (the natural subconscious reaction we have when night shifts to day and vice versa).

"Imagine flying across the country and getting jet-lagged," says Flynn-Evans. "It's very similar to what astronauts deal with on the International Space Station, only the stakes are much higher."

One significant negative effect, also noted in Flynn-Evans' research, is the effect of 'slam-switch', the process where astronauts have to radically alter their body clock in order to phase into the shift patterns onboard sites such as the International Space Station.

"Rapid schedule changes are a problem, but so is exposure to light at times when the astronauts are scheduled to sleep," adds Flynn-Evans. "The crewmembers will often look out of the cupola window to get a view of Earth during their scheduled sleep time, which can expose them to a bright blast of sunlight and inhibit their ability to sleep."

NASA is also working on new methods to improve astronaut sleeping conditions, such as the use of special blue LED lights to help reduce insomnia, and adding more home comforts to help its operators relax far more naturally. ●

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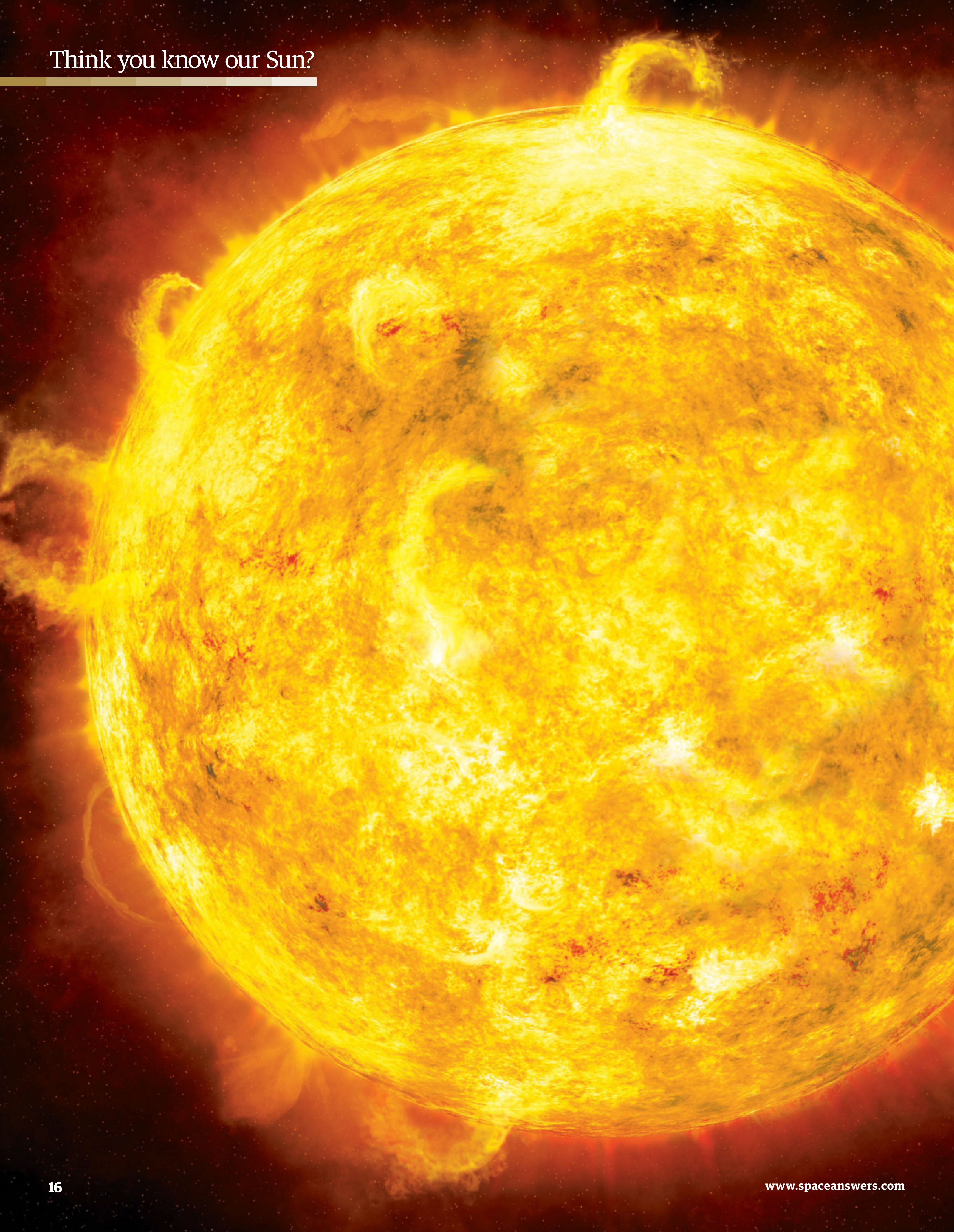


THINK YOU KNOW OUR SUN?

Despite its proximity, we're still in the dark when it comes to knowing everything about our star

Written by David Crookes

Carved on the walls and sarcophagi of the pyramids located at the vast ancient burial ground of Saqqara are mentions of Amun, the Ancient Egyptian god of creation. He was thought to reside inside the Sun and his role in Egyptian life became very important as a result. But only when he was later combined with the Sun god Ra to become the God of Kings, did he rise to be the most worshipped ruler of them all. He was, as the Hymn to Amun-Ra describes him, the "Lord of things that are" and it was recognition of the Sun's power as much as anything else.

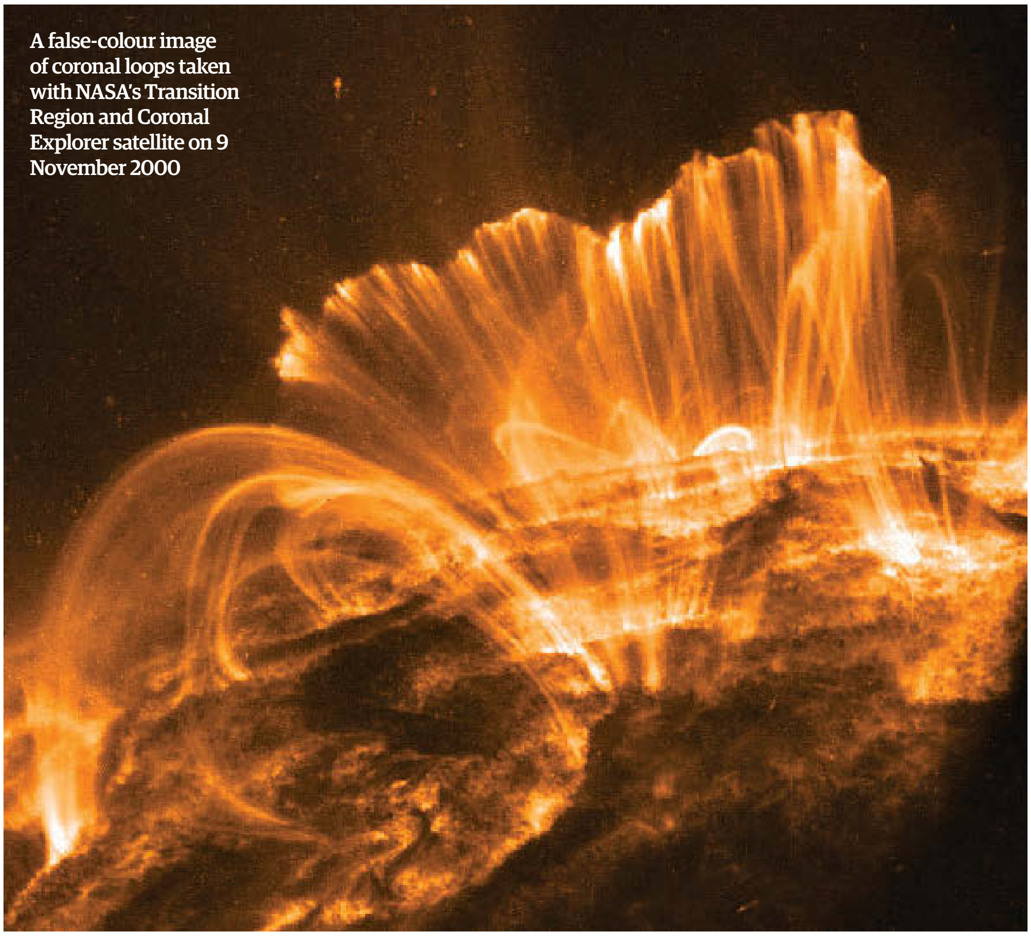
Fast forward to today though, and we know one thing for certain: no being – whether real or mythical – actually lives inside the Sun. Indeed, we understand that the Sun is one of billions of stars in the universe and that it has a surface temperature of 5,500 degrees Celsius (9,932 degrees Fahrenheit). We are certain that it has a radius just over 100 times that of Earth and that it's at the centre of our Solar System. And yet we don't know everything, which is why recent studies casting fresh light on the scorching yellow dwarf have been intriguing many a scientist.

"The observations of late have put a lot of theories under pressure," says Dr Scott McIntosh, director of the High Altitude Observatory at the National Center for Atmospheric Research in the US. "That, I have to say, is a very good thing because unlike any other star in the universe, we can observe the living life out of this one and, for me as a solar physicist, if we don't try and understand the star that is on our doorstep, then we haven't a hope of understanding the others." Over the past two decades, great strides have been made towards furthering our understanding of the Sun, from the launches of SOHO and STEREO – the former recently celebrated its 20th anniversary and the latter coming up to a decade of operation – to the Solar Dynamics Observatory (SDO) which launched in 2010. SDO's mission is to unlock the processes inside the Sun, on the Sun's surface and in its corona by using the most advanced spacecraft ever designed to study the star's behaviour.

In combination with other observational techniques, scientists have been able to view incredible phenomena, which allows them to better understand the Sun's electromagnetic patterns and learn more about the space weather experienced here on Earth. "It's really enabled a lot of cutting edge research," says Dr McIntosh.

Some of the observations are visually mind-blowing. In September last year, the SDO not only captured a close-up of plasma loops on the Sun's surface, but it also captured an image of the Earth

> "If we don't understand the star that is on our doorstep, then we haven't a hope of understanding the others" **Dr Scott McIntosh**


A false-colour image of coronal loops taken with NASA's Transition Region and Coronal Explorer satellite on 9 November 2000

The Solar Dynamics Observatory launched on 11 February 2010 in a bid to reveal the Sun's inner workings

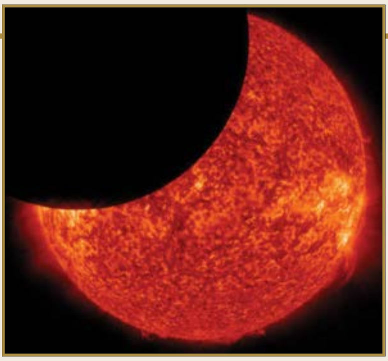
Discoveries of the Sun

Our understanding of our star has continued to grow as technology has advanced

Circa 20 BCE

Moon's role in eclipse explained

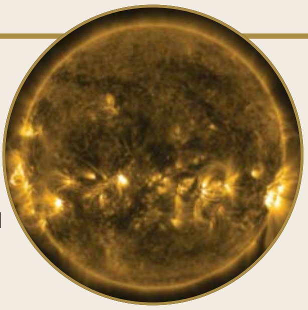
Chinese astronomer Liu Hsiang noted that solar eclipses were caused by the Moon moving across the Sun and blocking it out.



968 CE

Solar corona is described

The Byzantine historian Leo Diaconus was aged 18 when he described the solar corona as 'a dim and feeble glow'.



and Moon as they crossed the face of the Sun – a rare double eclipse. In October, a huge coronal hole was revealed on the Sun's surface, a temporary "symptom" of the magnetic field reaching out into space rather than looping on to the surface, allowing solar winds to be ejected faster than on other parts of the Sun. In that instance, the hole was 50 times the size of Earth.

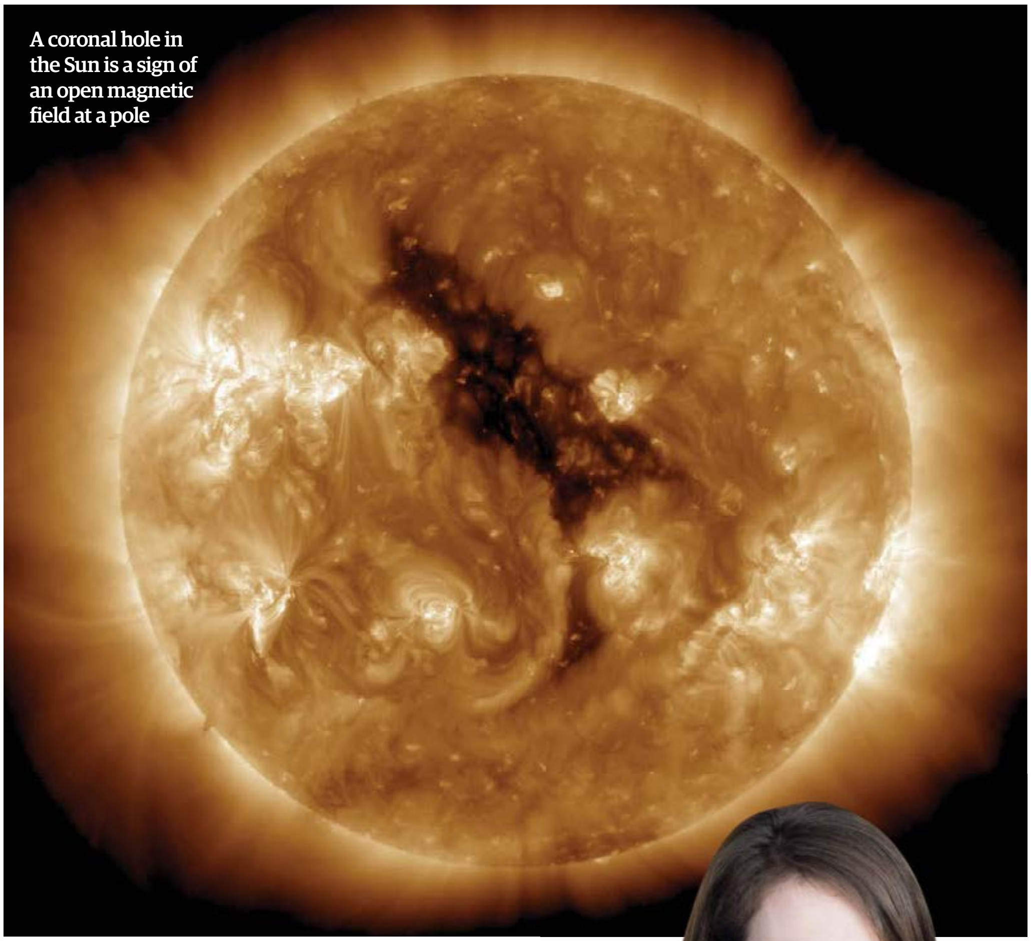
But the scientific advancements have been more impressive. In February last year, NASA's Deep Space Climate Observatory (DSCOVR) was launched to measure solar winds, replacing the ACE research satellite as the main warning system for solar magnetic storms. In November, the Mars Atmosphere and Volatile Evolution (MAVEN) mission showed that Mars may well have been hit by a solar storm which stripped away the planet's upper atmosphere. But it's no real surprise to hear that the Sun can be a wrecker. A lot of recent discoveries have centred on the star's potential impact on Earth and the wider Solar System.

Before we get to them, let's quickly look at the workings of the Sun, starting with its primary make up: 72 per cent hydrogen and 26 per cent helium, with trace amounts of heavier elements such as carbon, oxygen and neon. Within the Sun's dense and highly-pressurised core, hydrogen atoms smash into each other at speed, fusing the nuclei while producing heat and helium. Such nuclear fusion – the exact principle which chillingly inspired the atomic bomb – sends energy outwards, causing photons to bounce around the Sun's radiative zone, some 350,000 kilometres (220,000 miles) thick, before making their way to the convective zone where they zip along to the surface. The heat and light leave the Sun to travel towards the planets, reaching Earth after just eight minutes, providing us with warmth and daylight.

This is great for sunseekers and those who don't eat enough carrots, but ferocious activity on the solar surface has made solar physicists rather wary. The exterior of the Sun is in constant turmoil, hallmarked by solar flares of radiation that include white light, ultraviolet, X-rays and gamma rays, as well as coronal mass ejections (CMEs), which – put simply – are the casting of magnetic bubbles of charged particles into space. There may also be a new type of solar ejection that was discovered last year: large wave fronts in the Sun's atmosphere together with energetic particle emissions rich in helium-3. "The new phenomenon is like a kind of explosion," says Radoslav Bucik, head of the research team at the Max Planck Institute for Solar System Research (MPS), Johns Hopkins University, and NASA's Jet Propulsion Laboratory in the United States.

Such explosions can have an effect on Earth. They occur across the Sun thanks to a copious number of magnetic poles causing the plasma to rotate at different speeds in an act referred to as differential rotation. With some areas magnetically stronger than others, the field lines become twisted, usually above sunspots in the low solar atmosphere.

Despite an energy equivalent of 100 million megaton bombs, most resulting flares pass off without major consequence for us. But with the recent discovery of possible superflares by a team at the University of Warwick on the binary star KIC 9655129, that could change: if such a superflare occurred on our Sun, it would pack the power of one billion megaton nuclear bombs. Lead scientist Chloe Pugh says superflares could take place "once every 500 or 600 years" on Earth and there is a



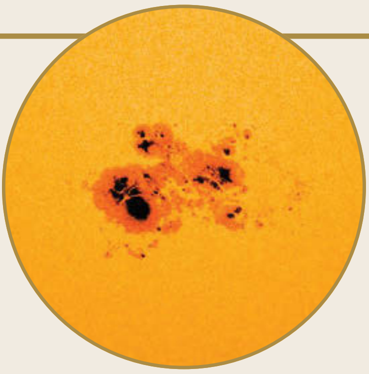
A coronal hole in the Sun is a sign of an open magnetic field at a pole

> "Superflares could take place once every 500 or 600 years on Earth and could cause long-term blackouts" **Chloe Pugh**

1609

Galileo sheds light on sunspots

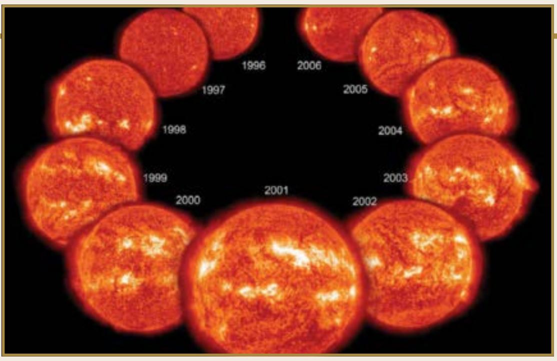
Galileo Galilei built his first telescope, which allowed him to observe sunspots and confirm that the Sun rotates.



1645

Maunder studies the magnetic cycle

Edward Maunder photographed and measured sunspots, discovering the solar latitudes at which they occurred had regular variation over 11-year cycles.

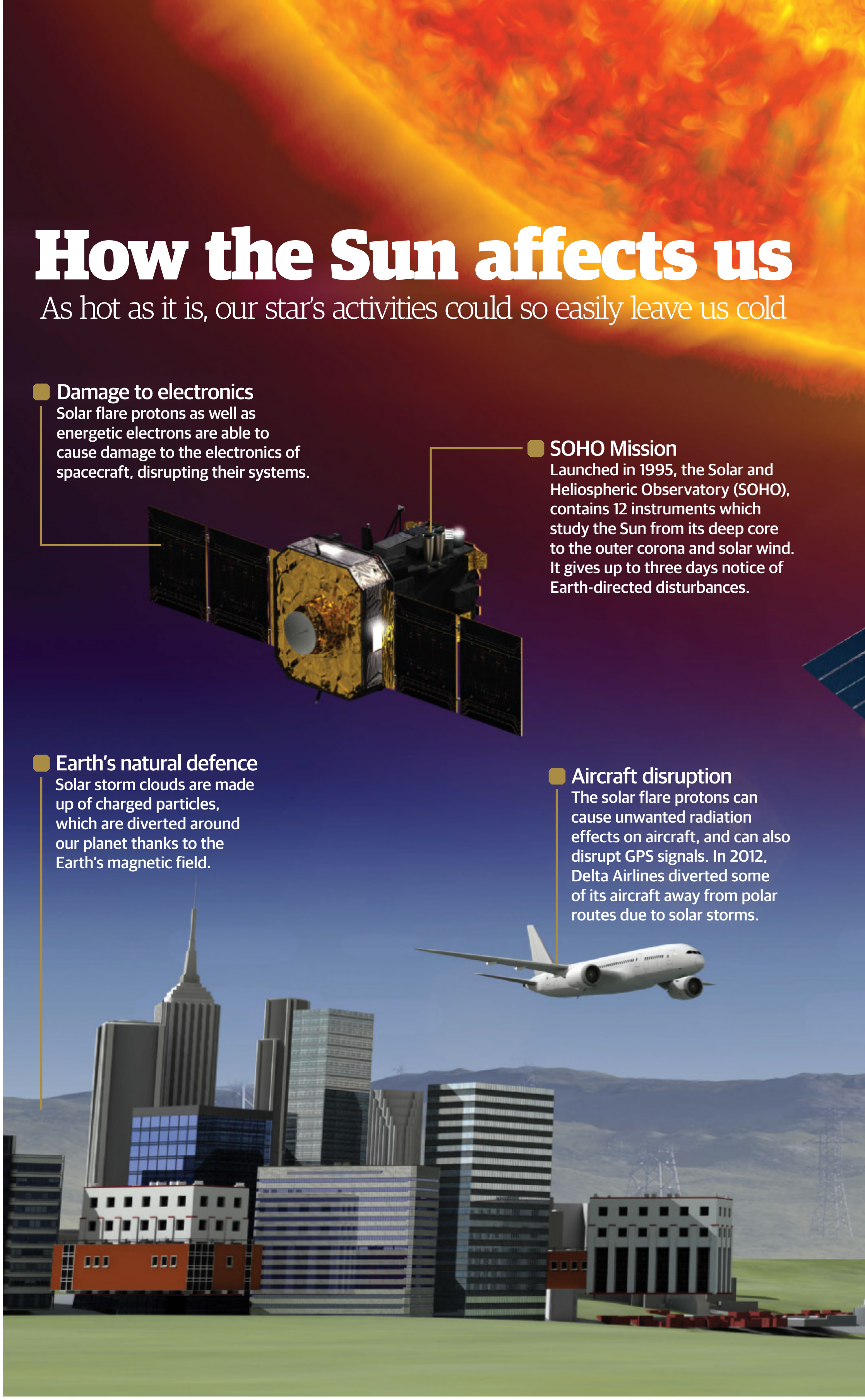


very real possibility that they could cause long-term blackouts. The study was based on the observations of 23 stars and Pugh says more Sun-like stars need to be observed to improve the estimate. She adds, that "there is evidence of past superflares occurring on the Sun during 774CE and 993CE in ice cores" and should the Earth be in the direct path of a superflare, then it would be very disruptive. "For the Earth, the atmosphere protects us from most of the harmful ultraviolet and X-ray radiation from flares, however, the radiation can alter the chemistry of the upper atmosphere, damage the ozone layer, and disrupt radio communications," Pugh tells us.

Although she stresses that the Earth's magnetic field can protect us from the worst of the charged particle radiation, for powerful solar storms some radiation can enter the atmosphere around the magnetic North and South Poles. "This would be hazardous for aircrew and passengers flying at high latitudes, and strong currents could be induced in power grids, causing large-scale power blackouts - this happened in 1989 in Quebec. In the near-Earth environment, satellites could be permanently damaged, or broken completely, and any astronauts in space would be in danger from radiation if there was not sufficient protection in their spacecraft."

Such phenomena are taken seriously. The White House's National Science and Technology Council has a National Space Weather Action Plan outlining a response to a solar storm and at the end of 2015, the US Department of Energy's Princeton Plasma Physics Laboratory reported that it may have identified the mechanism which halts CMEs before they leave the Sun. CMEs tend to release magnetic energy into the Solar System, although they can also collapse back towards the Sun. Associate research physicist Clayton Myers has found that this is determined by whether or not the guide magnetic field is strong enough to prevent the energy from being released. By looking out for these guide fields, solar physicists will be able to better predict whether an eruption is real or a false alarm. It also highlights that scientists still have much to discover about our Sun.

"While we understand the basics of most solar phenomena, there is a lot that is not well understood," confesses Chloe Pugh. "For example, we cannot directly see the interior of the Sun, and so cannot determine exactly how the magnetic field is generated. Also, it is not known why the atmosphere, or corona, of the Sun is much hotter than the surface of the Sun - this is known as the coronal heating problem. A mystery of solar flares is the fast reconnection problem, where models of magnetic reconnection suggest a timescale that is much too slow to explain flares, which occur on a much faster timescale. There have been some models proposed to



How the Sun affects us

As hot as it is, our star's activities could so easily leave us cold

Damage to electronics
Solar flare protons as well as energetic electrons are able to cause damage to the electronics of spacecraft, disrupting their systems.

SOHO Mission
Launched in 1995, the Solar and Heliospheric Observatory (SOHO), contains 12 instruments which study the Sun from its deep core to the outer corona and solar wind. It gives up to three days notice of Earth-directed disturbances.

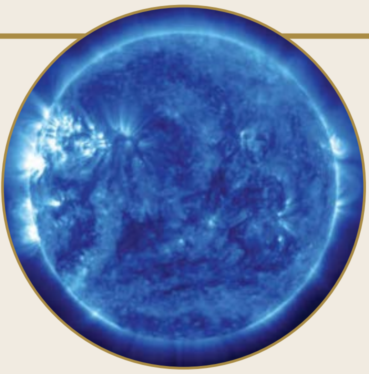
Earth's natural defence
Solar storm clouds are made up of charged particles, which are diverted around our planet thanks to the Earth's magnetic field.

Aircraft disruption
The solar flare protons can cause unwanted radiation effects on aircraft, and can also disrupt GPS signals. In 2012, Delta Airlines diverted some of its aircraft away from polar routes due to solar storms.

1800

Infrared and ultraviolet radiation

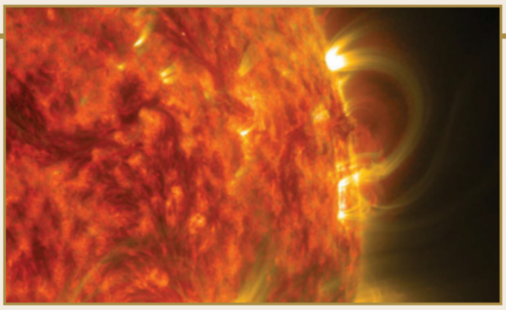
William Herschel discovered heat rays - infrared radiation as it became known - and the following year Johann Wilhelm Ritter found "chemical rays", now known as ultraviolet radiation.

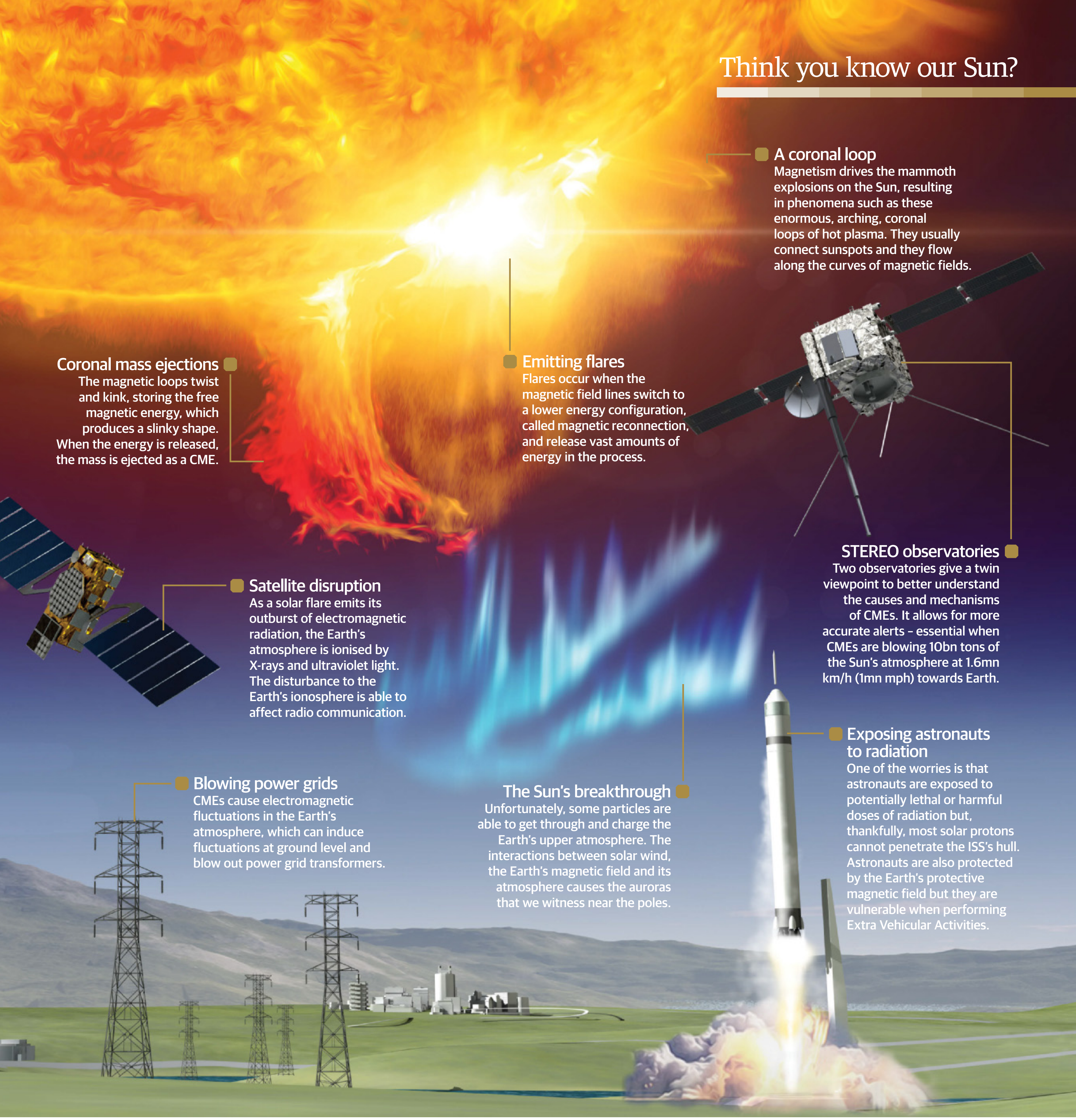


1859

Solar flare is recorded

Astronomers Richard Carrington and Richard Hodgson observed and recorded a solar flare. A huge geomagnetic storm was experienced on Earth.





A coronal loop

Magnetism drives the mammoth explosions on the Sun, resulting in phenomena such as these enormous, arching, coronal loops of hot plasma. They usually connect sunspots and they flow along the curves of magnetic fields.

Coronal mass ejections

The magnetic loops twist and kink, storing the free magnetic energy, which produces a slinky shape. When the energy is released, the mass is ejected as a CME.

Emitting flares

Flares occur when the magnetic field lines switch to a lower energy configuration, called magnetic reconnection, and release vast amounts of energy in the process.

STEREO observatories

Two observatories give a twin viewpoint to better understand the causes and mechanisms of CMEs. It allows for more accurate alerts – essential when CMEs are blowing 10bn tons of the Sun's atmosphere at 1.6mn km/h (1mn mph) towards Earth.

Satellite disruption

As a solar flare emits its outburst of electromagnetic radiation, the Earth's atmosphere is ionised by X-rays and ultraviolet light. The disturbance to the Earth's ionosphere is able to affect radio communication.

Blowing power grids

CMEs cause electromagnetic fluctuations in the Earth's atmosphere, which can induce fluctuations at ground level and blow out power grid transformers.

The Sun's breakthrough

Unfortunately, some particles are able to get through and charge the Earth's upper atmosphere. The interactions between solar wind, the Earth's magnetic field and its atmosphere causes the auroras that we witness near the poles.

Exposing astronauts to radiation

One of the worries is that astronauts are exposed to potentially lethal or harmful doses of radiation but, thankfully, most solar protons cannot penetrate the ISS's hull. Astronauts are also protected by the Earth's protective magnetic field but they are vulnerable when performing Extra Vehicular Activities.

1919

General theory of relativity

Einstein's theory was tested by Arthur Eddington during a total solar eclipse and proved that light could be bent by the gravitational force of the Sun.

1951

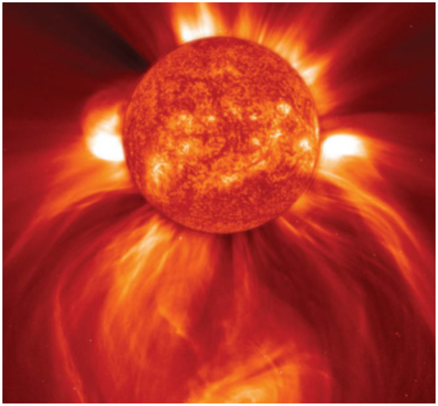
Solar wind found to exist

Ludwig Biermann observed comet tails and noted the role of solar winds, which are charged gas particles ejected from the Sun.

Think you know our Sun?

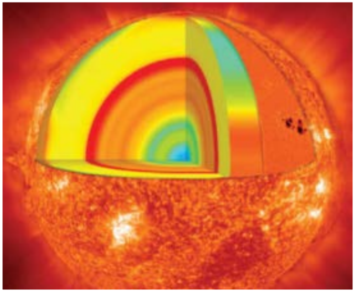
All about the Sun

Interesting facts that will shed more light on your knowledge of our star



The Sun outputs 385 billion billion megawatts of energy. It dwarfs Earth's most powerful nuclear power station, Kashiwazaki-Kariwa Nuclear Power Plant, which has a net capacity of 7,965 megawatts.

The distance between the Sun and the Earth is 150mn km (93mn mi) – you would have to drive around the Earth over 3,700 times to match it.



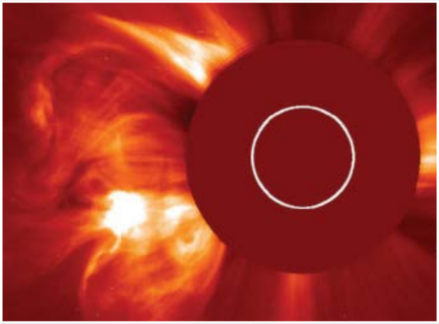
The Sun's core is 15,000,000°C (27,000,000°F) – about 4,000 times the melting point of a diamond.

The Sun is 4.6 billion years old. The oldest tools found on Earth are around 3.3 million years old.

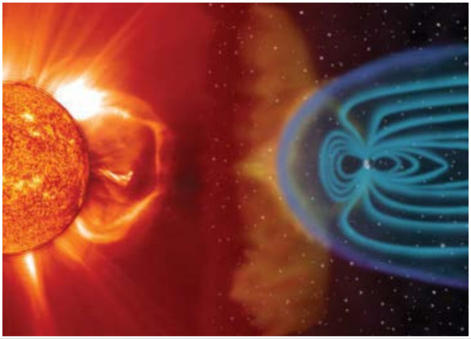
You would need about four trillion trillion 100-watt lightbulbs to equal the brightness of the Sun.

The Sun's plasma is the same state of matter as the substances found in fluorescent lights and plasma TV screens.

When the Sun emits a solar flare, on average the amount of energy released is equivalent to 100 million megaton hydrogen bombs all exploding at the same time.



Solar winds travel at around 400 km/s (250 mil/s). The fastest recorded wind gust on Earth was taken during Cyclone Olivia in 1996. It was 0.11km/s (0.07mi/s).



A bolt of lightning can reach a temperature of 29,727°C (53,540°F) – around fives times the surface temperature of the Sun!

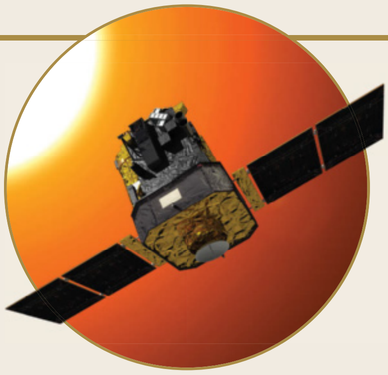
Earth receives around 15 billion trillion joules of solar energy each day – roughly equivalent to 10,000 times global daily energy consumption.

Over one million Earths could fit inside the Sun – as could nearly 1,000 Jupiters.

1995

SOHO is launched

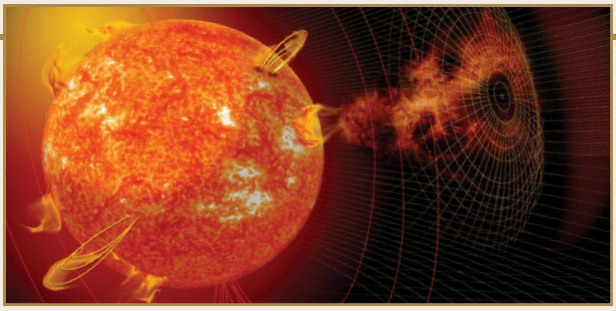
Following the launch of the SOHO satellite, it was discovered that coronal mass ejections (CMEs) occur each day.

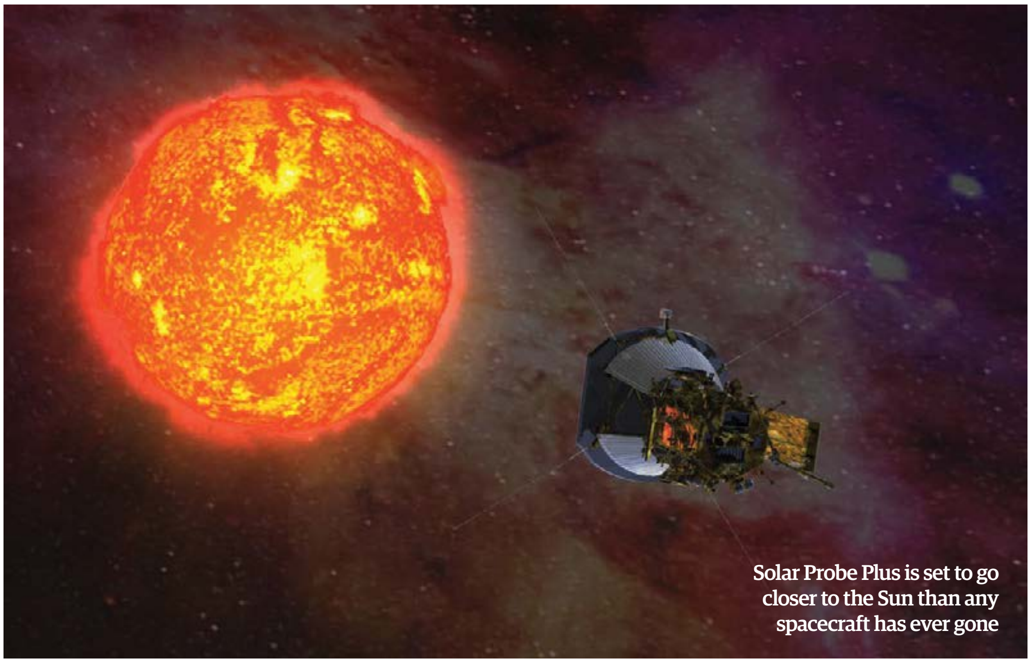


2005

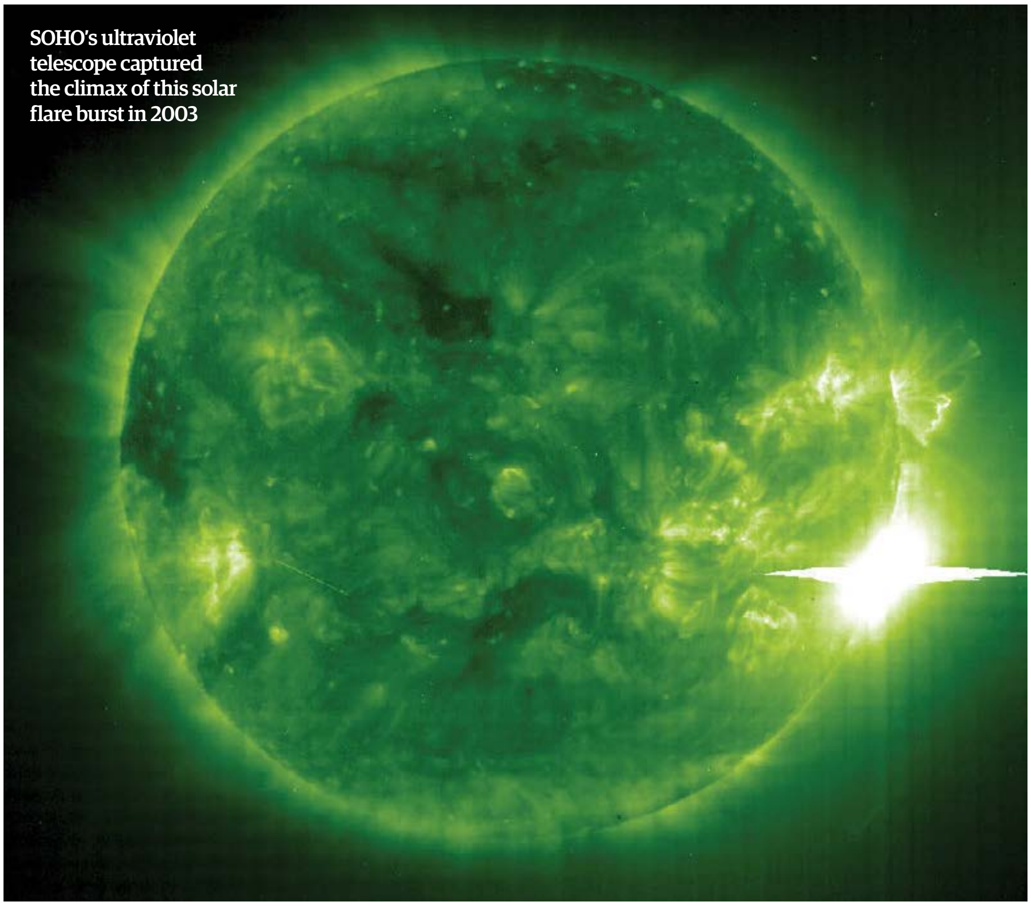
Decade of SOHO discoveries

In taking the most detailed measurements of the Sun's surface, SOHO found that CMEs blast a "highway" through space.





Solar Probe Plus is set to go closer to the Sun than any spacecraft has ever gone



SOHO's ultraviolet telescope captured the climax of this solar flare burst in 2003

explain all of these problems, but it can be difficult to prove which are correct."

The coronal heating problem has puzzled solar physicists since 1939. They cannot say for certain why the corona - the outermost part of the Sun's atmosphere - is hotter than the surface of the Sun. But they have narrowed it down to magnetohydrodynamic waves, which travel from the core with the consequence of heating up the coronal plasma and the possibility of the magnetic field reconnecting in the corona causing nanoflares. In December 2014, NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) focussed on the Sun and noted the emission of high-energy X-rays, the likes of which are seen from black holes. Such X-rays would be generated from nanoflares and it confirmed the 2007 finding of X-ray jets spraying out hundreds of times each day at 3.2 million kilometres (two million miles) per hour. Observed by Japan's Hinode spacecraft, it too was seen to help explain the superheating of the Sun's corona.

Further to that though, in 2013, Michael Hahn and Daniel Wolf Savin from Columbia University's Astrophysics Laboratory observed a polar coronal hole where magnetic field lines stretch from the surface of the Sun into space. They saw that magnetic waves - called Alfvén waves - contain sufficient energy to heat the corona and that, because they deposit the energy at a low height, the heat is able to spread. But how they convert the energy has been unknown.

In September 2015, Dr Hahn and Dr Savin became excited by observations made by teams at Nagoya University and the National Astronomical Observatory (NOS) in Japan. They saw resonant absorption, which is a wave process in which repeated waves add energy to the plasma. A certain type of plasma wave was being converted to a more turbulent type of motion and the resulting friction and electric currents were heating the solar material. "For over 30 years, scientists hypothesised a mechanism for how these waves heat the plasma," said Dr Patrick Antolin of the NOS. "An essential part of this process is called resonant absorption - and we have now directly observed resonant absorption for the first time."

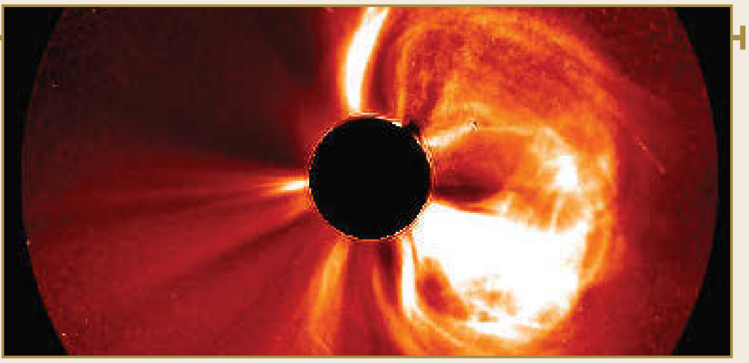
But the trick to making sense of many of the Sun discoveries is to bring them together as a whole, which is why some solar physicists tend not to look at one particular aspect of the Sun but at the star in general. "Instead of looking at the spots, flares and coronal mass ejections and treating them all individually like a dermatologist, I'm a GP and look at the whole Sun and how the atmosphere connects," says Dr McIntosh.

"It's like playing KerPlunk - if a piece of magnetic field somewhere on the farside changes, it has a catastrophic affect on the piece facing Earth," he adds. "This is a realisation largely born from the cutting edge 'all of the Sun, all of the time' observations of the past decade." Yet the fact that it's hard to directly observe much solar phenomena makes life difficult. "The fact that the Sun has a dynamo is questioned because we can't directly observe it, for example," he says, of the physical process which is said to generate the Sun's magnetic field. But here too, there have been some strides.

2006

3D imaging of the Sun

STEREO allowed 3D images to be taken of the Sun for the first time, while the Solar Dynamics Observatory launched in 2010.



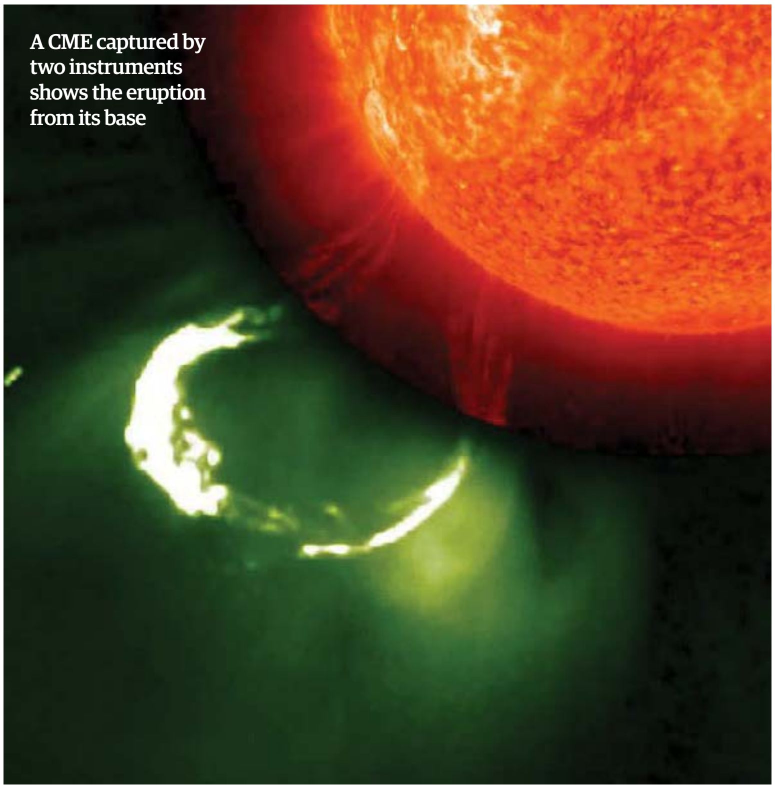
Our Sun has long been found to have an 11-year activity cycle, producing electric currents according to the flow of the Sun's hot, ionised gases. At the peak of each cycle, scientists witness lots of sunspots and solar flares together with a number of coronal mass ejections, which is the casting into space of magnetic bubbles of charged particles. Yet we are still far from a complete understanding of how the dynamo works, and scientists have been frustrated that models have been unable to fully account for all of the Sun's behaviour.

During 2015, however, Professor Valentina Zharkova, from Northumbria University, found the irregular 11-year heartbeat may be produced by not one but two dynamos, one close to the surface and the other within the convection zone. The model shows magnetic wave components appearing in pairs, both with the same frequency, yet offset so that they fluctuate between the northern and southern hemispheres, and Dr Zharkova says it has proved to be accurate to 97 per cent. Using the model, she predicts that the two waves will become increasingly offset during what is called Cycle 25, which starts in 2020. By Cycle 26 in 2030, the waves will be completely out of sync and they will separate into the hemispheres, ceasing to interact, thereby cancelling each other out.

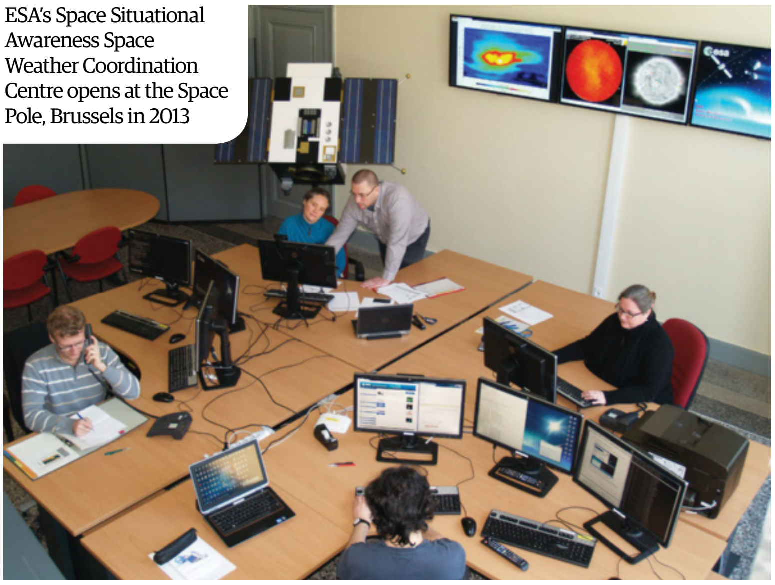
"Solar activity will fall and you will have this Maunder Minimum which we saw in the 17th century for 60 years from 1645," Dr Zharkova tells us, referring to a period in history known for its mini ice age - the Little Ice Age. "At that time, there was a freeze and something similar could happen next time. But how it could decrease I cannot say yet. It is only a calculation."

Indeed, it may well be that many of the current theories are blown out of the water when the Solar Probe Plus is launched in 2018. It is set to go closer to the Sun than any other spacecraft ever launched, protected by a heat shield that can survive 1,371 degrees Celsius (2,500 degrees Fahrenheit) and blasts of radiation. It would allow scientists to determine the structure and dynamics of the magnetic fields at the sources of solar wind and trace the flow of energy that heats the corona and accelerates the solar wind. "It's a good development," says Dr McIntosh. "When you think this star on our doorstep could literally wipe us out, and will do eventually, you can't really gamble." ●

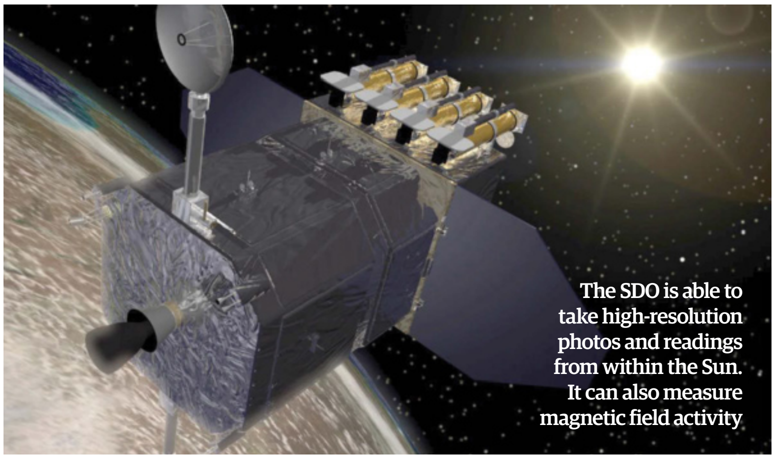
> "If a piece of magnetic field on the Sun's farside changes, it has a catastrophic affect on the piece that's facing Earth"



A CME captured by two instruments shows the eruption from its base



ESA's Space Situational Awareness Space Weather Coordination Centre opens at the Space Pole, Brussels in 2013



The SDO is able to take high-resolution photos and readings from within the Sun. It can also measure magnetic field activity

It is important to keep check on space weather to protect astronauts on Extra Vehicular Activities (EVAs)

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Gemini 8: 50 years on

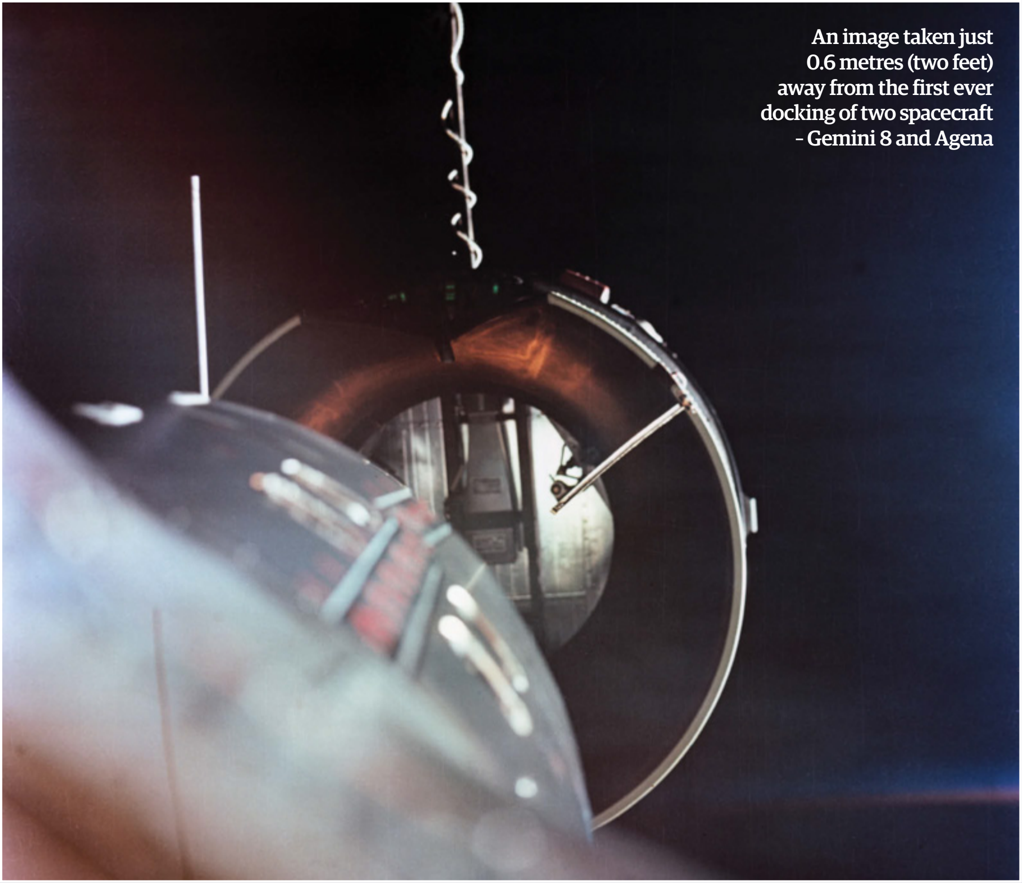
From successfully docking two crafts in space to a horrifying, stomach-turning problem…

Neil Armstrong was the first person to walk on the Moon but Apollo 11 in 1969 was not his first foray into space. On 16 March 1966, NASA launched the two-man, three-day Gemini 8 mission from Cape Kennedy (now Cape Canaveral). Armstrong was the commander and, together with David Scott, spent more than six hours performing nine manoeuvres to rendezvous with the unmanned Gemini Agena Target Vehicle, which launched earlier in the day.

Having completed the first ever successful docking in orbit of two vehicles, control of Gemini 8 was transferred to Agena. At this point, Scott should have begun preparing for an extravehicular activity (EVA) to retrieve a nuclear radiation experiment from the front of Gemini's spacecraft adapter and in order to activate a micrometeoroid experiment on the Agena. Instead, however, disaster struck within just 30 minutes of Gemini 8 docking with the Agena Target Vehicle.

The combined spacecraft had veered 30 degrees off the horizon and couldn't be corrected. A malfunctioning thruster sent the vehicle violently tumbling and twisting around its vertical axis. When control was returned to Gemini, it yawed, rolled and pitched, faster and faster. Even as Gemini was disengaged, it revolved once every second.

With the crew in danger of blacking out, the mission was aborted and the re-entry system activated. This stabilised the spacecraft and allowed Gemini to land in the sea 1,000 kilometres (621 miles) south of Yokosuka in Japan. It was a disappointment that the mission had to be aborted, but at least - ten hours and 44 minutes after launch - Armstrong and Scott were safely back on Earth.



An image taken just 0.6 metres (two feet) away from the first ever docking of two spacecraft - Gemini 8 and Agena

Neil Armstrong and David Scott await the recovery ship following splashdown of Gemini 8, after the mission was aborted

© NASA

ENTER THE COSMIC BATTLEFIELD

VIOLENT UNIVERSE

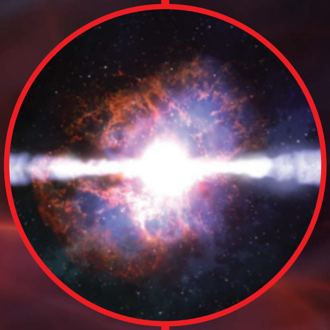
The cosmos is not the serene place it first appears – it is full of aggressive offenders

Written by Colin Stuart

Top 5 most destructive objects

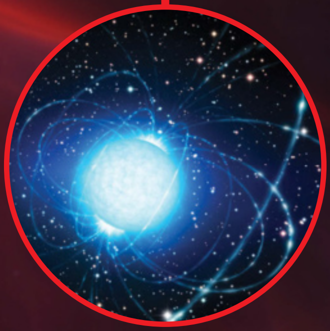
Gamma ray bursts
Caused either when a massive star collapses into a black hole or when two neutron stars collide, the total gamma ray energy emitted is 100 trillion trillion times more than the largest nuclear weapon ever tested on Earth.

Supernovae
An explosion, which occurs upon the death of a star, supernovae are at least eight times more massive than our Sun. A supernova can commonly release twice the amount of energy as a typical gamma ray burst.



Hypernovae
Some supernovae can be particularly brutal. Known as hypernovae, these events are associated with the origin of long gamma ray bursts. The total amount of energy released can be 100-times greater than an ordinary supernova.

Quasars
The most energetic form of Active Galactic Nuclei (AGN), a single quasar can release as much energy in a second as the Sun can release in 100,000 years. They can even be 100 times as luminous as an entire galaxy.



Magnetars
A particularly vicious form of neutron star, the strength of a magnetar's magnetic field is a billion times stronger than any magnet created by scientists on Earth. Such a setup fires high energy X-rays and gamma rays into space for 10,000 years.

As ultraviolet radiation cascades down from space, Earth's place as a life-friendly planet is under threat. The surface of our world is bathed in this high-energy radiation and it penetrates our oceans to depths of 75 metres (246 feet). The damage is catastrophic. The intense glare fries ocean plankton and those organisms which survive divert all their energy to repairing their DNA rather than photosynthesising. Oxygen levels drop as carbon dioxide levels rise. The knockout blow for many larger species comes as dwindling plankton numbers offer scant food resources, with the effect rocketing up the food chain.

Thankfully this fictional future is very unlikely, but what would have caused such devastation? The answer is a gamma ray burst (GRB). They often emit as much energy in a few seconds as our entire galaxy does in a year. If such a volley of gamma rays were to strike our planet, it would rip molecules in our atmosphere apart, releasing an army of ultraviolet photons to devastate the world's biosphere. Luckily, these events are rare, particularly in our own Milky Way. In fact, we've never observed one in our galaxy. Even if one were to go off, it would have to be aligned almost perfectly with Earth. However, studying them reveals just how violent our universe can be.

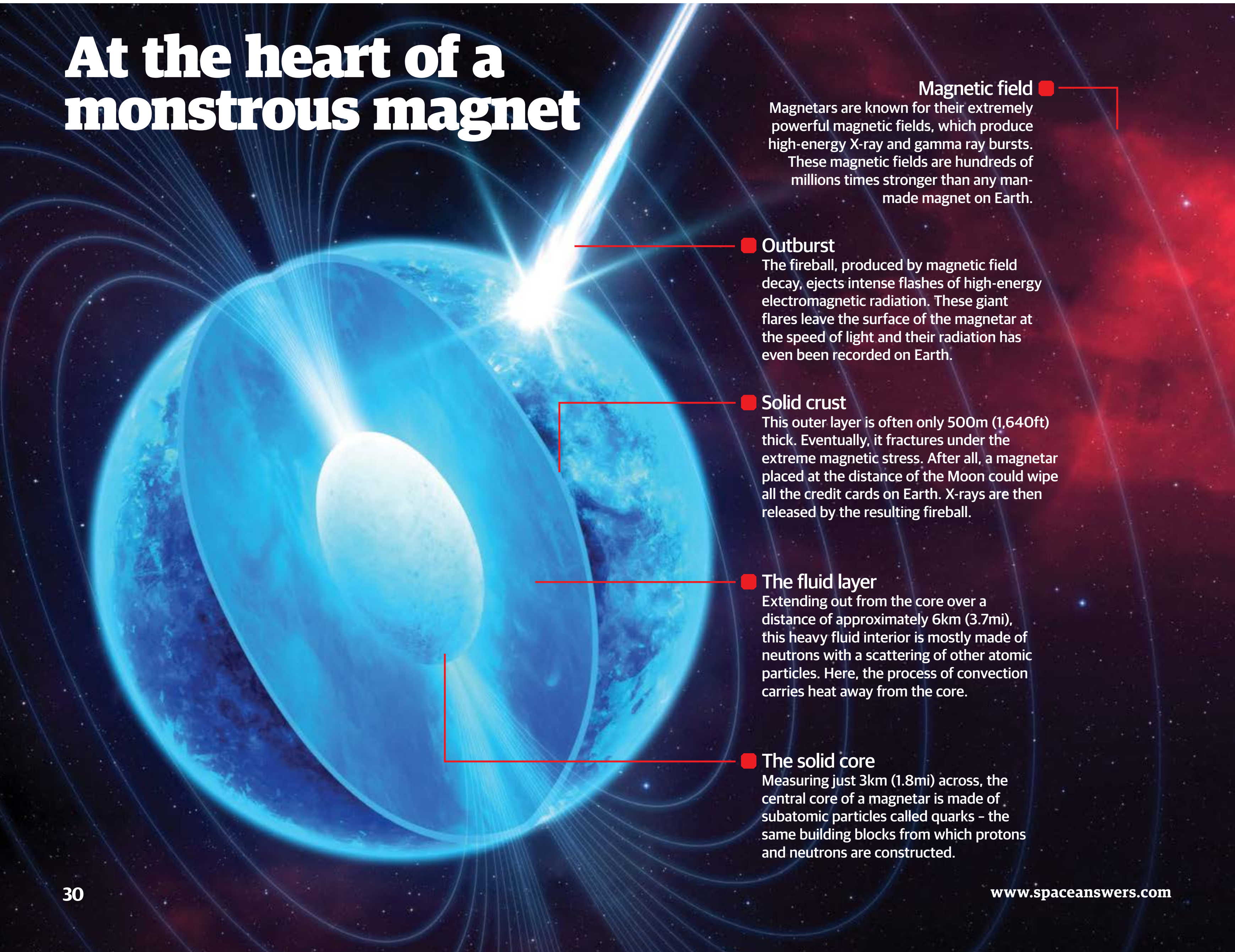
As the majority of GRBs observed by astronomers are in distant galaxies, working out exactly what causes them is notoriously tricky. However, most researchers agree that they are related to the death of stars. When a star at least eight-times bigger than the Sun begins to die, it alters the way it fuels itself. During the main chunk of its lifetime it was converting hydrogen into helium via nuclear fusion. However, it now starts to fuse helium into carbon and begins to bloat outwards. The core continues to fuse heavier and heavier elements until it creates a dense, iron core. The core then collapses under its own weight, before rebounding and sending a shockwave through the star's outer layers, causing it to explode as a Type II supernova – an event so energetic it can outshine all the stars in a galaxy and be seen even during daylight hours.

GRBs are associated with a particularly vicious form of supernova, known as a hypernova, which can be up to 50 times more energetic than the ordinary variety. They are thought to form when the iron core of a star at least 30 times more massive than the Sun collapses to form a black hole. Twin jets of energetic radiation surge away from the region close to the black hole and the gamma rays are believed to be produced by collisions between the jets and the outer layers of the star.

At least that is the favoured origin mechanism for around 70 per cent of observed GRBs, those that last longer than two seconds. These are known as

> "A gamma ray burst often emits as much energy in a few seconds as our entire galaxy does in a year"

At the heart of a monstrous magnet



Magnetic field
Magnetars are known for their extremely powerful magnetic fields, which produce high-energy X-ray and gamma ray bursts. These magnetic fields are hundreds of millions times stronger than any man-made magnet on Earth.

Outburst
The fireball, produced by magnetic field decay, ejects intense flashes of high-energy electromagnetic radiation. These giant flares leave the surface of the magnetar at the speed of light and their radiation has even been recorded on Earth.

Solid crust
This outer layer is often only 500m (1,640ft) thick. Eventually, it fractures under the extreme magnetic stress. After all, a magnetar placed at the distance of the Moon could wipe all the credit cards on Earth. X-rays are then released by the resulting fireball.

The fluid layer
Extending out from the core over a distance of approximately 6km (3.7mi), this heavy fluid interior is mostly made of neutrons with a scattering of other atomic particles. Here, the process of convection carries heat away from the core.

The solid core
Measuring just 3km (1.8mi) across, the central core of a magnetar is made of subatomic particles called quarks – the same building blocks from which protons and neutrons are constructed.

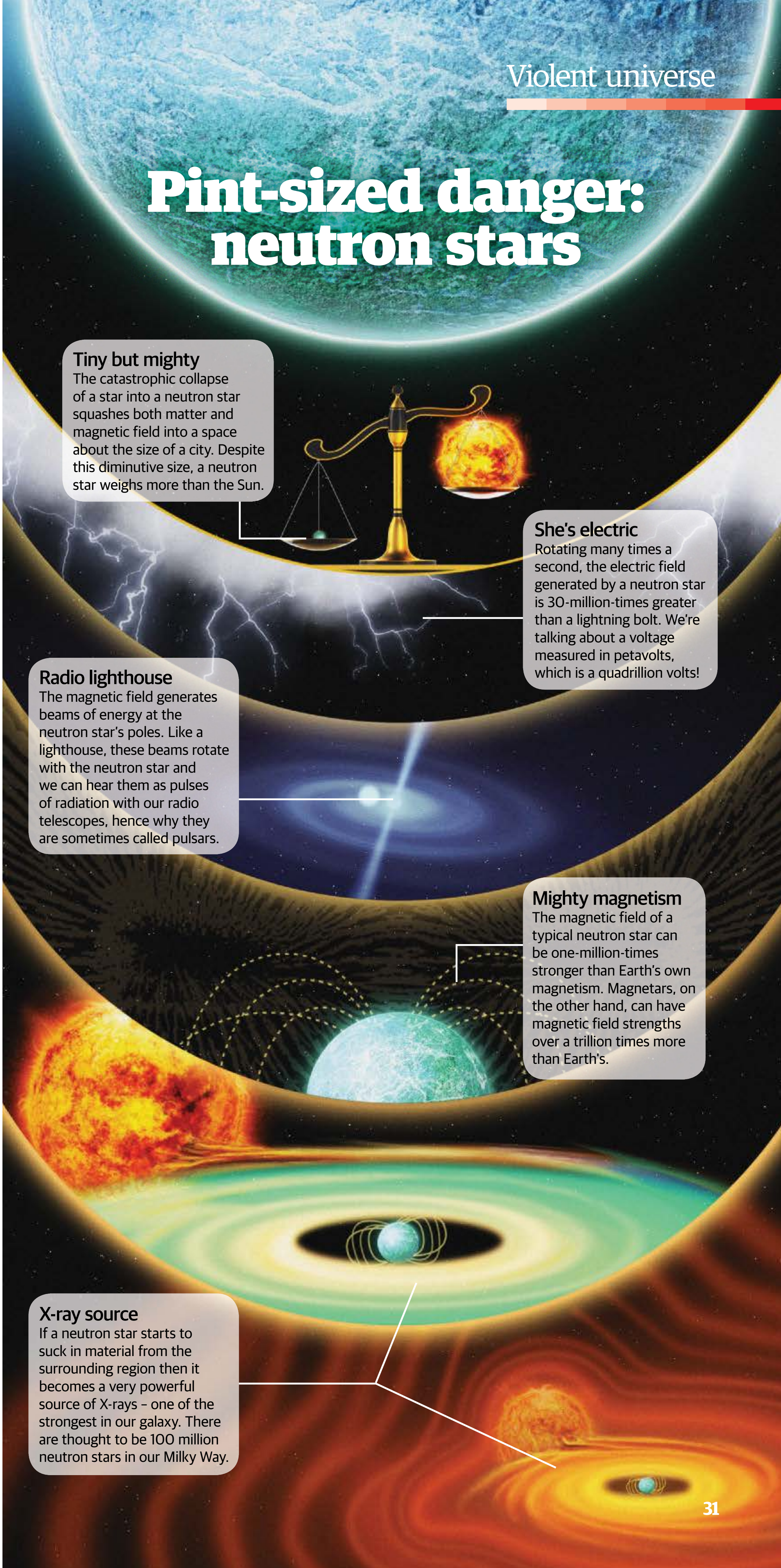
"long gamma ray bursts". However, roughly 30 per cent of GRBs are much shorter, typically lasting just 0.2 seconds. Rather than the collapse of a single star, these short gamma ray bursts are believed to originate from the collision of two neutron stars – the remnants of dead stars smaller than those which form black holes. The size of a city, a neutron star is so dense that a teaspoon full of its material weighs more than a mountain range and their magnetic fields can be a trillion times stronger than our Sun's. Computer simulations show that when two neutron stars spiral inwards towards each other they merge to form a black hole. The magnetic fields merge, too, and the overall strength of magnetism is boosted by a thousand times. Eventually, the new black hole's magnetic field aligns into jets, which can power a short GRB.

Not content with being responsible for these mighty events, neutron stars are also thought to be behind another of the universe's rogues gallery of violent offenders: magnetars. Souped-up versions of single neutron stars, they boast a significantly stronger magnetic field. It is estimated that ten per cent of neutron stars end up as this enhanced variety. With a rotational period of at least one second, they also spin more slowly than their traditional counterparts, which can rotate dozens of times in the same period. Their stronger magnetic field can yield intense flashes of gamma rays and X-rays, but not for long – the typical lifetime of a magnetar is just 10,000 years. A blink of an eye in astronomical terms. And, there are thought to be at least 30 million extinct magnetars in our Milky Way galaxy alone.

Sticking with the merging remnants of dead stars, there is another type of supernova, which is sometimes the result of two white dwarfs colliding together. Less massive than neutron stars or black holes, white dwarfs are the leftovers from stars about the size of the Sun. If two Sun-like stars were orbiting around each other in a binary system, when they both die the resulting white dwarfs can collide with each other. However, there is a limit to how massive a single white dwarf can be – known as the Chandrasekhar limit – and a wave of nuclear fusion will rip apart any white dwarf that ventures too close to it. The resulting Type 1a supernova releases 200 million billion times more energy than the Sun provides to the Earth in an entire year. Again, enough to briefly outshine the galaxy it resides in.

Analysing these explosions in relatively nearby galaxies has allowed astronomers to measure the rate at which the universe has expanded in the past. However, if we are searching for the universe's most violent objects then we have to travel far away from the local universe to the very furthest reaches of the cosmos, where we find quasars. They are the brightest objects in the universe, form part of a group of objects astronomers refer to as Active Galactic Nuclei (AGN) and get their name from the contraction of "quasi-stellar". The luminosity of a single quasar can be up to 100,000-times greater than our entire Milky Way galaxy. They represent the highly energetic cores of some of the earliest, and therefore most distant, galaxies in the universe.

The secret of their power lies in a very similar mechanism to that of GRBs but on a much larger scale. It is thought that large galaxies form when



Pint-sized danger: neutron stars

Tiny but mighty
The catastrophic collapse of a star into a neutron star squashes both matter and magnetic field into a space about the size of a city. Despite this diminutive size, a neutron star weighs more than the Sun.

She's electric
Rotating many times a second, the electric field generated by a neutron star is 30-million-times greater than a lightning bolt. We're talking about a voltage measured in petavolts, which is a quadrillion volts!

Radio lighthouse
The magnetic field generates beams of energy at the neutron star's poles. Like a lighthouse, these beams rotate with the neutron star and we can hear them as pulses of radiation with our radio telescopes, hence why they are sometimes called pulsars.

Mighty magnetism
The magnetic field of a typical neutron star can be one-million-times stronger than Earth's own magnetism. Magnetars, on the other hand, can have magnetic field strengths over a trillion times more than Earth's.

X-ray source
If a neutron star starts to suck in material from the surrounding region then it becomes a very powerful source of X-rays – one of the strongest in our galaxy. There are thought to be 100 million neutron stars in our Milky Way.

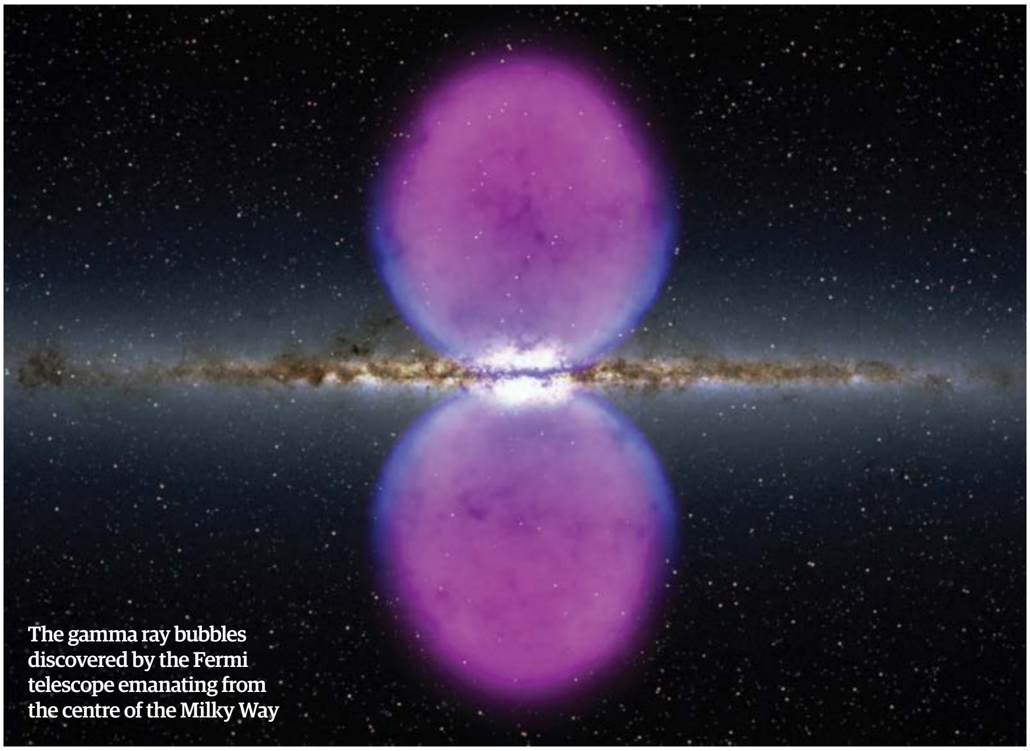
much smaller galaxies merge together. If each small galaxy had a reasonably big black hole at its centre then they will combine in the newly created galaxy to form a supermassive black hole with a mass greater than a billion Suns.

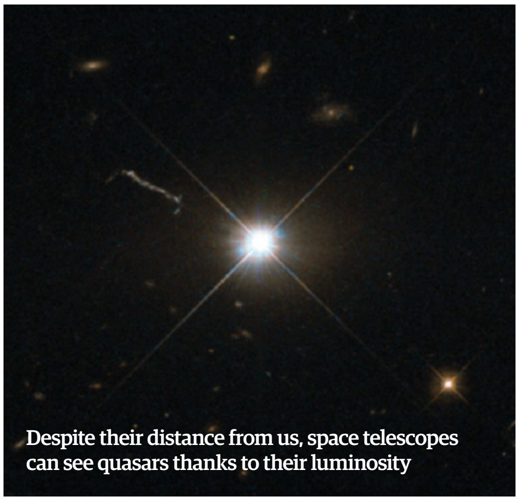
As this new behemoth starts to devour the surrounding material, the magnetic field around the black hole eventually sprouts two distinct jets of radiation, shooting out from the compact galactic centre like a lighthouse beam. The angle at which we observe this beam determines what we call it. If we see the beam at an angle then that's a quasar. Look straight into the beam and you have yourself a blazar. Finally, if you're looking at right angles to the beam astronomers know it as a radio galaxy. The study of AGNs is still a relatively new area of astronomy, with observations by the Hubble Space Telescope sending what we knew about them sky-rocketing. Yet one of the biggest mysteries surrounding them is why the nucleus of the Milky Way isn't currently anywhere near as active as some of these more distant galaxies. After all, observations suggest our galaxy is centred around a supermassive black hole with a mass equivalent to 4 million Suns.

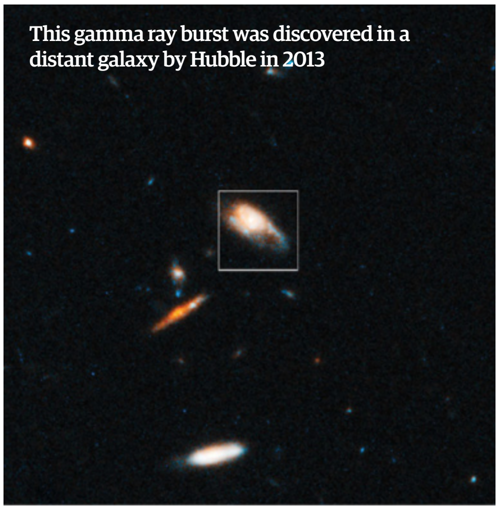
There is some evidence, however, that the Milky Way hasn't always been so serene. In 2010, the team behind the Fermi Gamma Ray Space Telescope announced the discovery of the so-called Fermi bubbles – giant gamma ray structures extending for 30,000 light years on each side of the galactic centre. Their presence points towards a sizeable and rapid eruption of energy close to the Milky Way's black hole several million years ago. In this eruption, gas and other material was driven out at millions of kilometres, or miles, per hour.

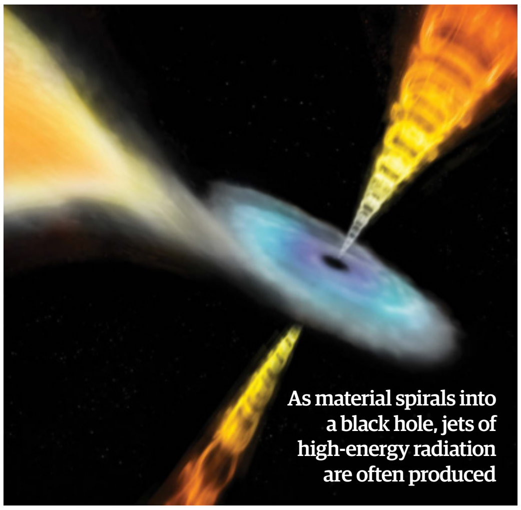
Two explanations are currently on offer for these remarkable structures. The first is that the area close to the galactic centre underwent a period of unprecedented star formation, with many of the stars exploding together as supernovae almost simultaneously. The other is that around the same time our supermassive black hole woke up and, starved from its hibernation, went on a feeding frenzy. If it turns out to be the latter, we should be thankful that our black hole effectively goes to sleep for extended periods of time. A healthier appetite would likely flood the Milky Way with intense bursts of lethal radiation and the rest of the violent universe would be the least of our problems. ■

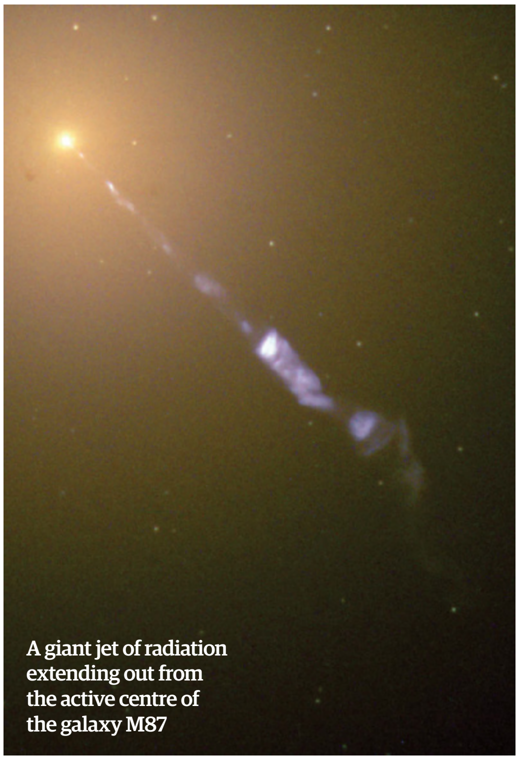
> "Giant gamma ray structures were discovered extending for 30,000 light years either side of the galactic centre"


The gamma ray bubbles discovered by the Fermi telescope emanating from the centre of the Milky Way

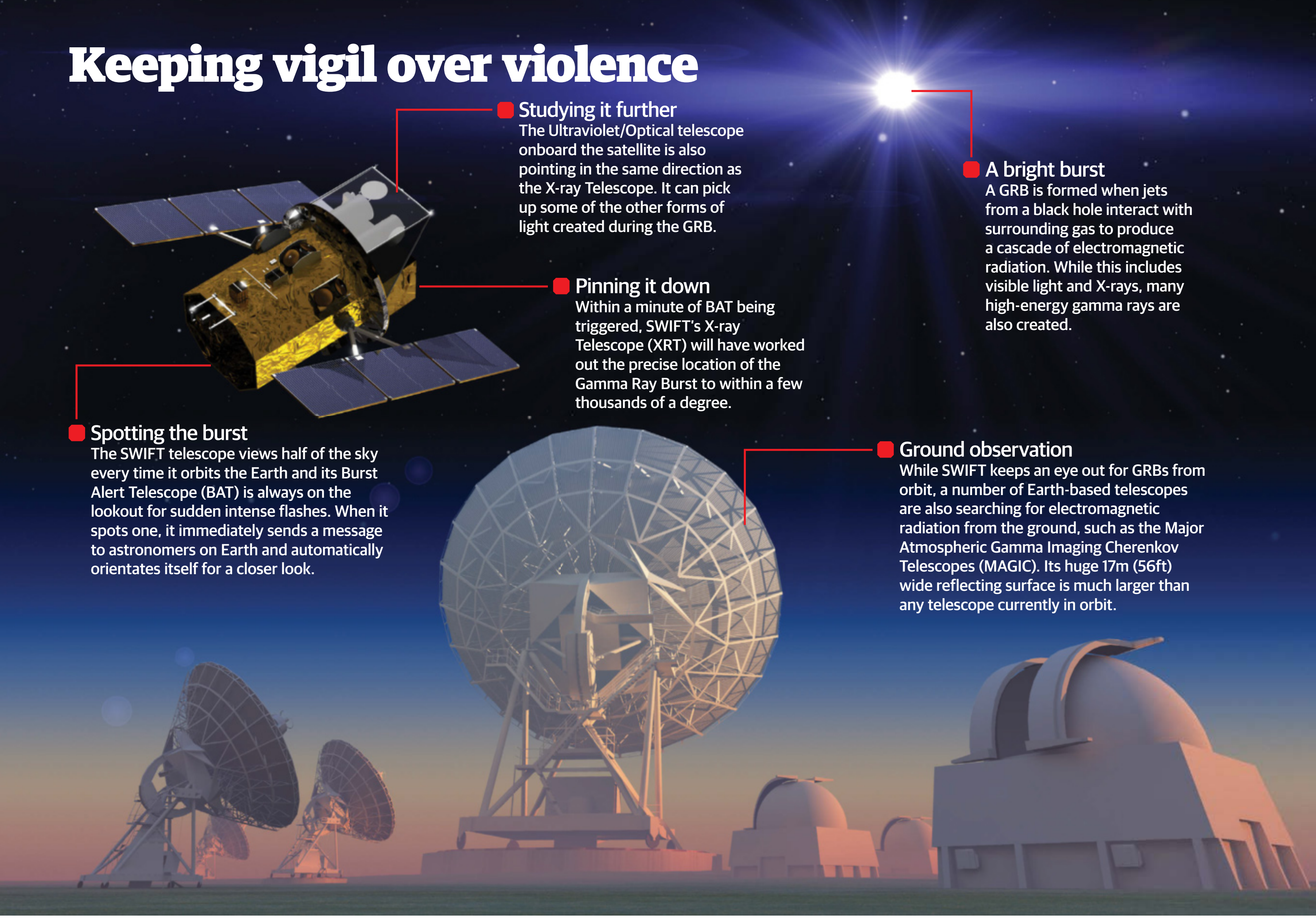

Despite their distance from us, space telescopes can see quasars thanks to their luminosity


This gamma ray burst was discovered in a distant galaxy by Hubble in 2013


As material spirals into a black hole, jets of high-energy radiation are often produced


A giant jet of radiation extending out from the active centre of the galaxy M87

Keeping vigil over violence



Studying it further

The Ultraviolet/Optical telescope onboard the satellite is also pointing in the same direction as the X-ray Telescope. It can pick up some of the other forms of light created during the GRB.

A bright burst

A GRB is formed when jets from a black hole interact with surrounding gas to produce a cascade of electromagnetic radiation. While this includes visible light and X-rays, many high-energy gamma rays are also created.

Pinning it down

Within a minute of BAT being triggered, SWIFT's X-ray Telescope (XRT) will have worked out the precise location of the Gamma Ray Burst to within a few thousands of a degree.

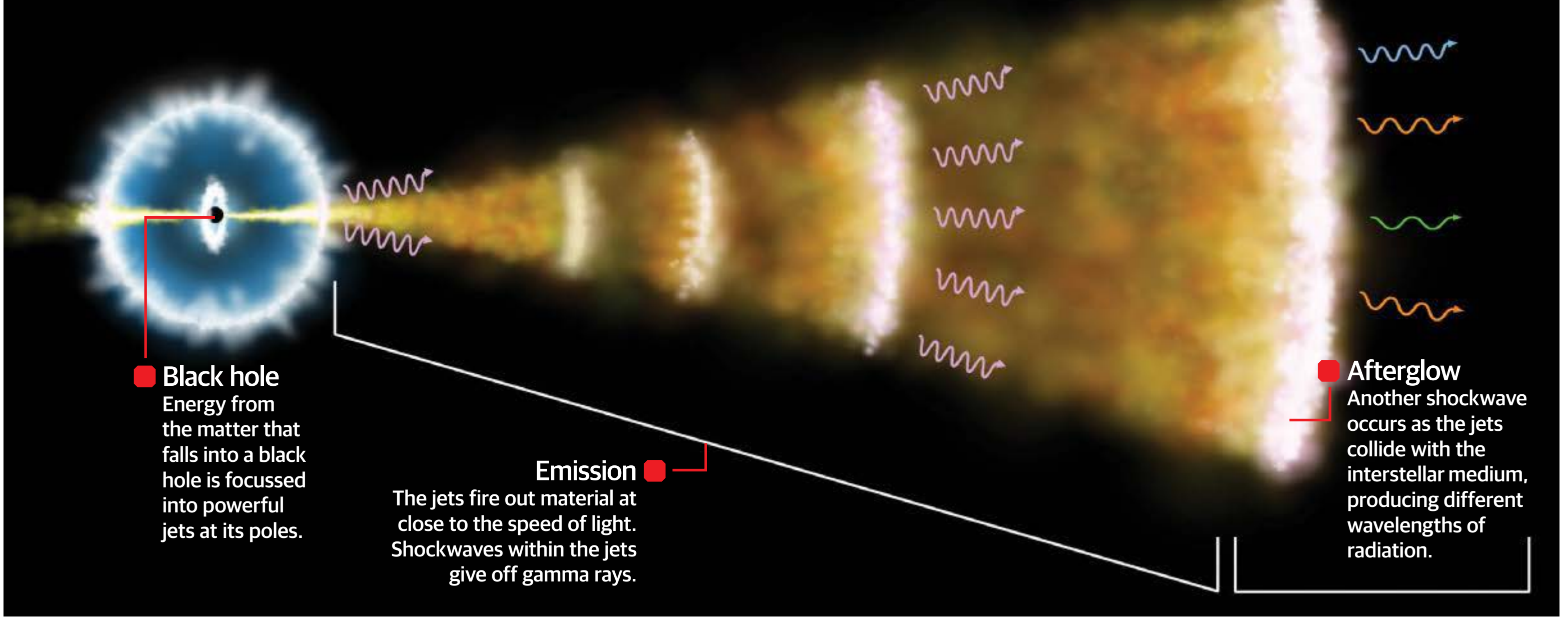
Spotting the burst

The SWIFT telescope views half of the sky every time it orbits the Earth and its Burst Alert Telescope (BAT) is always on the lookout for sudden intense flashes. When it spots one, it immediately sends a message to astronomers on Earth and automatically orientates itself for a closer look.

Ground observation

While SWIFT keeps an eye out for GRBs from orbit, a number of Earth-based telescopes are also searching for electromagnetic radiation from the ground, such as the Major Atmospheric Gamma Imaging Cherenkov Telescopes (MAGIC). Its huge 17m (56ft) wide reflecting surface is much larger than any telescope currently in orbit.

How gamma ray bursts are made



Black hole

Energy from the matter that falls into a black hole is focussed into powerful jets at its poles.

Emission

The jets fire out material at close to the speed of light. Shockwaves within the jets give off gamma rays.

Afterglow

Another shockwave occurs as the jets collide with the interstellar medium, producing different wavelengths of radiation.

© Tobias Roetsch; Nicholas Forder; Adrian Mann; ESO; NASA; ESA; Hubble; Dana Berry

Explorer's Guide

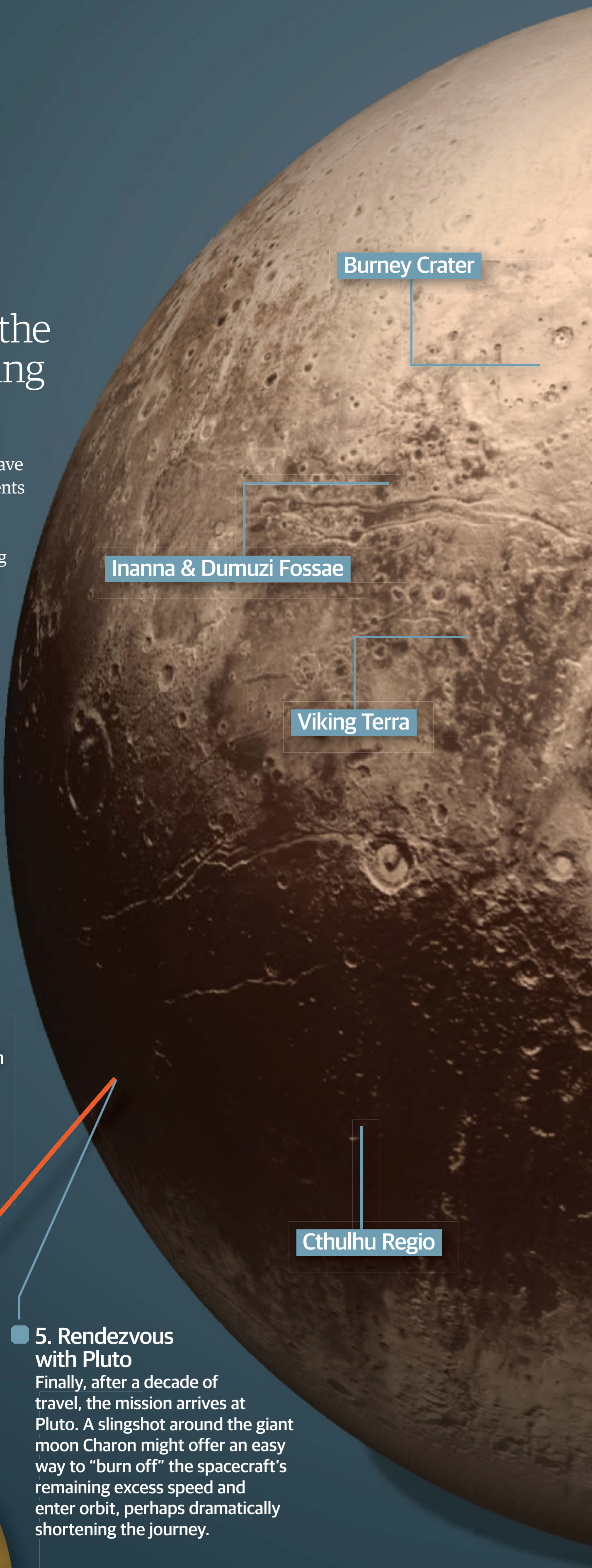
Pluto

One of the largest worlds in the Kuiper Belt of the outer Solar System, Pluto plays host to surprising contrasts and possible geological activity

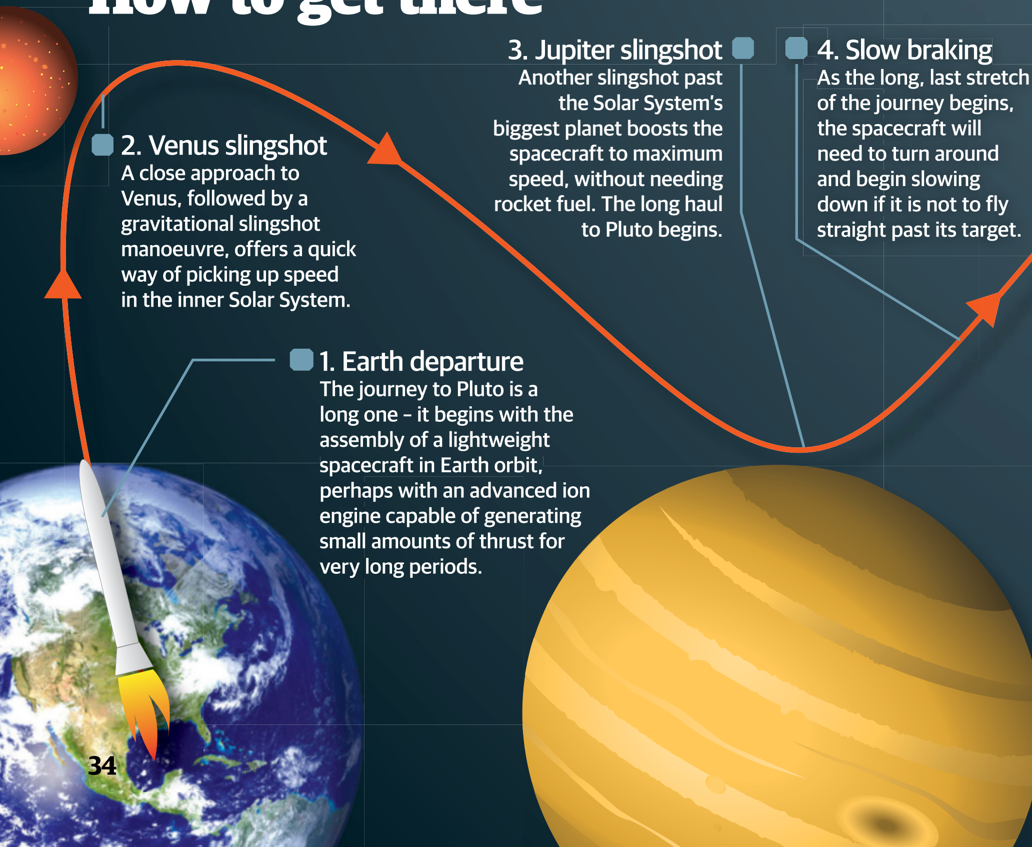
When compared to the major planets of our Solar System, Pluto is tiny, with a diameter just half that of Mercury. Yet, when it was discovered in 1930 it was heralded as the "ninth planet", a tag that stuck until surprisingly recently. This was partly because Pluto was found during a deliberate planetary search, and because it simply didn't fit in anywhere else.

Some astronomers suggested, almost immediately, that Pluto might just be the brightest object in a belt of small worlds orbiting beyond Neptune, but it was not until 1992 that astronomers using the Hubble Space Telescope detected another small object in similar orbit, and the previously hypothetical "Kuiper Belt" was proved real. In 2006, the International Astronomical Union declared that Pluto should no longer be considered a major planet, but was, instead, one of several "dwarf planets". Nevertheless, Pluto is a fascinating world. Its tiny size as seen from Earth makes it almost impossible to observe in detail, but in 1978 astronomers discovered that it has a giant moon called Charon, which has a diameter more than half of Pluto's. Four smaller satellites have since been added to the system. Measurements of Charon's orbit revealed that Pluto's axis is tilted sharply to its orbit at an angle of 119.5 degrees from upright. The system's changing orientation relative to Earth means that twice in each long Plutonian year, Pluto and Charon go through a series of 'mutual eclipses', periodically blocking parts of each other's light.

This allowed astronomers to compile the first basic maps of Pluto's brightness and colour in the 1980s. Meanwhile, studies of the light from faint stars about to pass behind the planet itself showed slight dips, indicating the presence of an atmosphere on Pluto. In 2006, NASA launched New Horizons, its first spaceprobe towards Pluto: the results of its 2015 flyby have given us a much better understanding of this intriguing world.



How to get there



2. Venus slingshot
A close approach to Venus, followed by a gravitational slingshot manoeuvre, offers a quick way of picking up speed in the inner Solar System.

1. Earth departure
The journey to Pluto is a long one – it begins with the assembly of a lightweight spacecraft in Earth orbit, perhaps with an advanced ion engine capable of generating small amounts of thrust for very long periods.

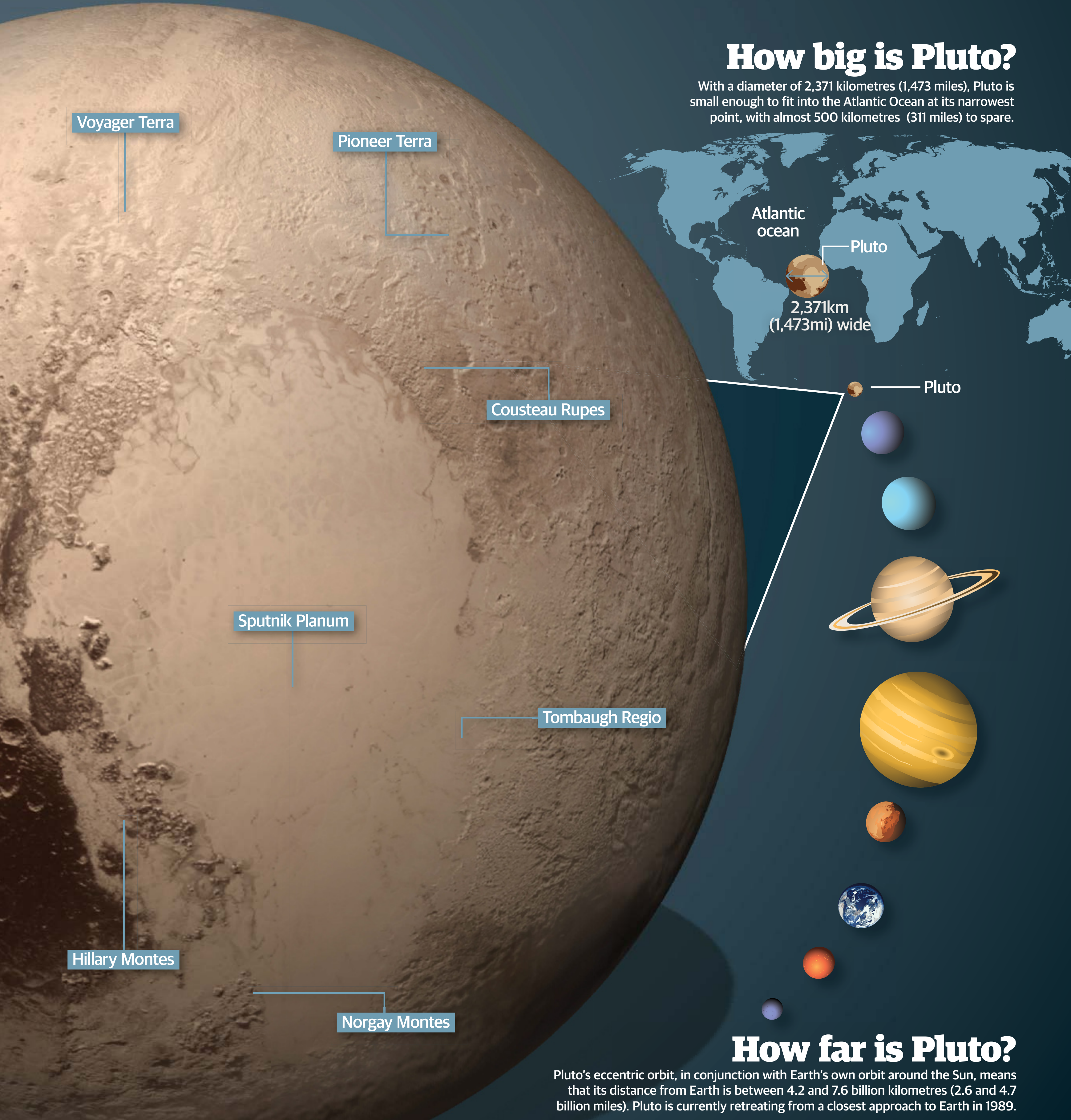
3. Jupiter slingshot
Another slingshot past the Solar System's biggest planet boosts the spacecraft to maximum speed, without needing rocket fuel. The long haul to Pluto begins.

4. Slow braking
As the long, last stretch of the journey begins, the spacecraft will need to turn around and begin slowing down if it is not to fly straight past its target.

5. Rendezvous with Pluto
Finally, after a decade of travel, the mission arrives at Pluto. A slingshot around the giant moon Charon might offer an easy way to "burn off" the spacecraft's remaining excess speed and enter orbit, perhaps dramatically shortening the journey.

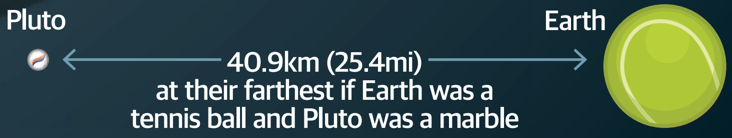
How big is Pluto?

With a diameter of 2,371 kilometres (1,473 miles), Pluto is small enough to fit into the Atlantic Ocean at its narrowest point, with almost 500 kilometres (311 miles) to spare.



How far is Pluto?

Pluto's eccentric orbit, in conjunction with Earth's own orbit around the Sun, means that its distance from Earth is between 4.2 and 7.6 billion kilometres (2.6 and 4.7 billion miles). Pluto is currently retreating from a closest approach to Earth in 1989.


Pluto
Earth
40.9km (25.4mi) at their farthest if Earth was a tennis ball and Pluto was a marble

Top sights to see on Pluto

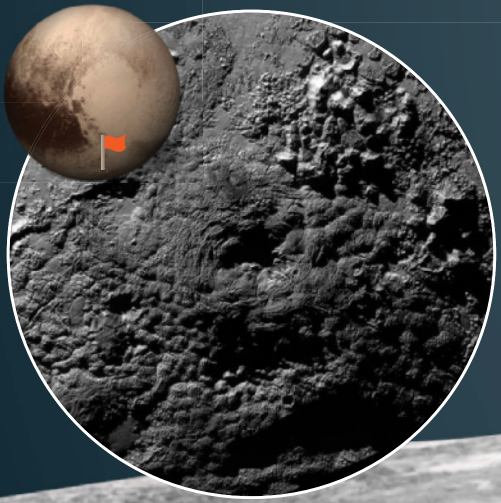
Early maps of Pluto made from Earth orbit showed contrasts between dark and bright and reddish and greyish terrains – matching the features uncovered by New Horizons. But, one problem caused by Pluto's extreme tilt is that a large portion of the southern hemisphere is in permanent darkness, so little is known about what lies hidden south of the equator.

Prominent features of the northern hemisphere and the equator are the bright, heart-shaped Tombaugh Regio, and the dark rugged Cthulhu Regio. As on many planets of the Solar System, the number of craters on particular surfaces is used to estimate their age, and this shows that Tombaugh has two distinct halves: the eastern lobe is aged and heavily cratered, while Sputnik Planum to the west boasts a smooth plain, suggesting a recent geological origin. Several mountains, each up to four kilometres (2.5 miles) high, are found around Tombaugh – to grow this high they must have considerable internal strength, suggesting a composition of frozen water rather than other chemical ices.

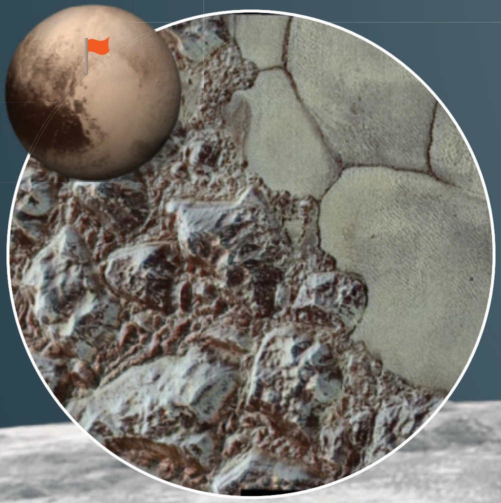
Sputnik Planum appears to be covered in a thick layer of frozen nitrogen – features around its edges strongly suggest glacier-like flows as the ice creeps across the surface, filling in nearby depressions. The bright plain is divided into irregular segments by intervening darker troughs, and is also spotted with dark pits that all run in parallel directions. These are probably evidence of a process called sublimation – when the Sun's heating effect is at its greatest, nitrogen ice is transforming directly into gas, which helps build up Pluto's thin atmosphere. Darker spots naturally warm up more and become the sources of vapour, darkening still further as their surface ice is removed, and as the weak prevailing winds draw the sublimating ice in a southeasterly direction.

Nearby Cthulhu Regio, in contrast, is heavily cratered and its surface has probably not been re-covered in billions of years. Its dark, brownish-red colour is thought to be caused by tarry chemicals called tholins, created when cosmic rays (high-energy particles from the Sun) trigger reactions between methane and nitrogen in the atmosphere. Cthulhu is the largest in a series of dark plains that run close to Pluto's equator, nicknamed the 'Brass Knuckles'.

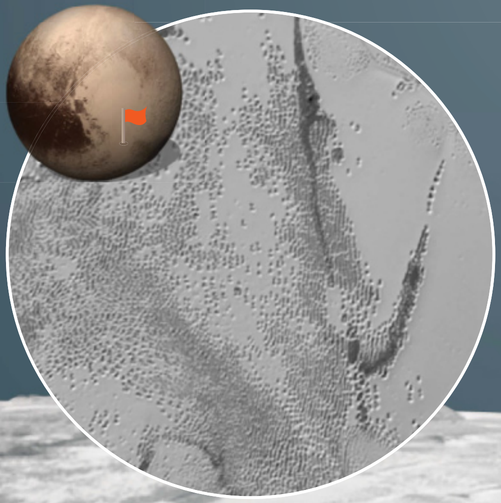
Wright Mons
A mountain to the south of Sputnik Planum, it is 160km (99mi) wide, with a depressed central caldera 56km (35mi) across. It's one of a pair that may have produced icy cryovolcanic eruptions in Pluto's past.

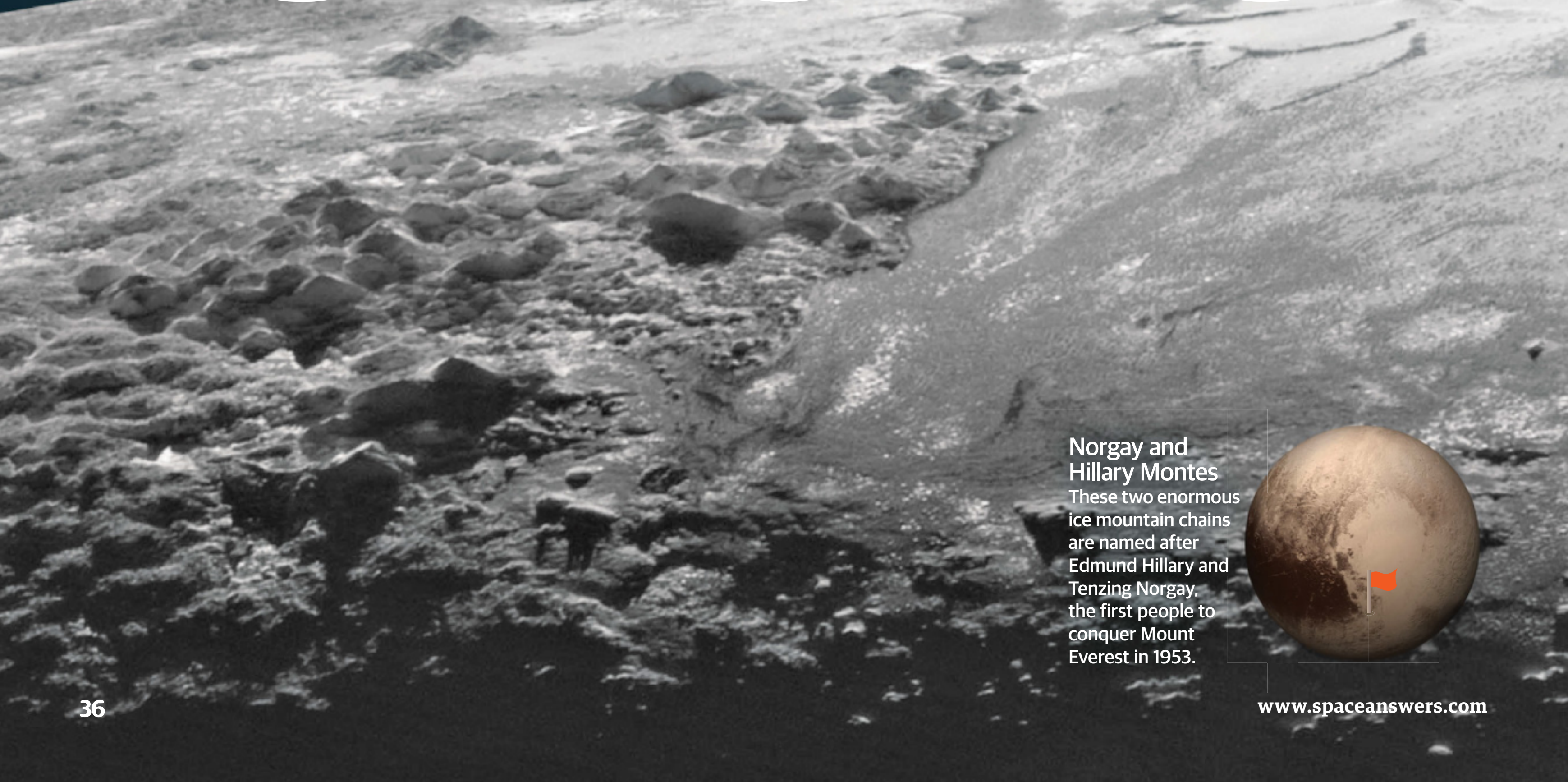


Sputnik shoreline
At the edge of Sputnik Planum, the rippled icy plain overlaps older, crumpled terrain. Here, blocks of Pluto's water-ice crust appear jammed together in a region known as the al-Idrisi mountains.



Sublimation pits
These speckles scattered across the surface of Sputnik Planum are most likely a result of ice erosion where sunlight warms darker patches of the surface more than bright ones.





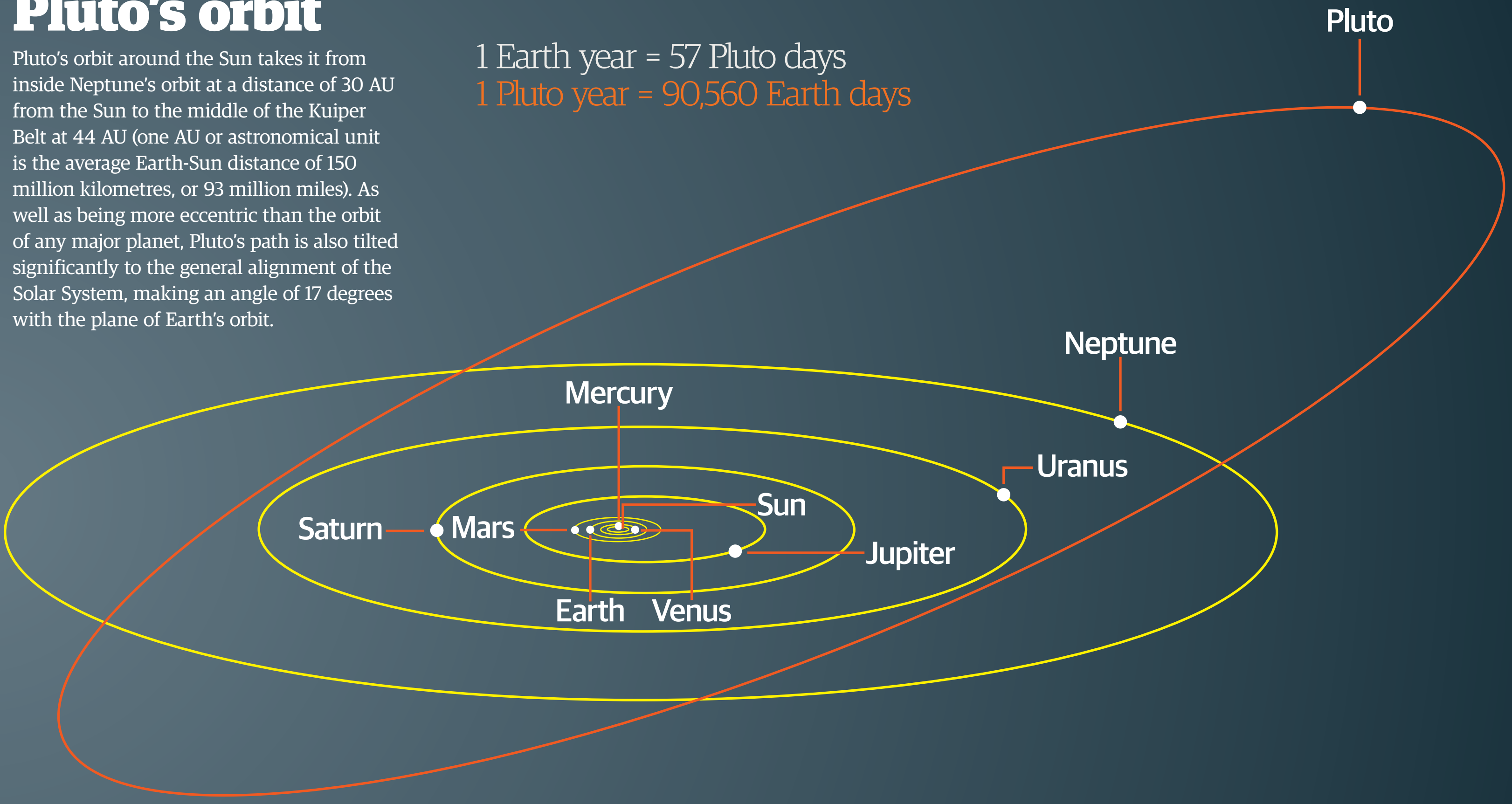
Norgay and Hillary Montes
These two enormous ice mountain chains are named after Edmund Hillary and Tenzing Norgay, the first people to conquer Mount Everest in 1953.

Pluto's orbit

Pluto's orbit around the Sun takes it from inside Neptune's orbit at a distance of 30 AU from the Sun to the middle of the Kuiper Belt at 44 AU (one AU or astronomical unit is the average Earth-Sun distance of 150 million kilometres, or 93 million miles). As well as being more eccentric than the orbit of any major planet, Pluto's path is also tilted significantly to the general alignment of the Solar System, making an angle of 17 degrees with the plane of Earth's orbit.

1 Earth year = 57 Pluto days

1 Pluto year = 90,560 Earth days



Pluto in numbers

6.4 *Pluto's rotation period in Earth days (also Charon's orbital and rotation period)*

247.94 Pluto's orbital period in Earth years – the time it takes for one cycle around the Sun

0.006 *Pluto's volume in terms of Earth's*

Weather forecast

-223°C
-369°F

Pluto's thin atmosphere is dominated by nitrogen but also contains small amounts of methane and carbon monoxide, all produced by sublimation of its surface ices. Atmospheric pressure is about 100,000-times less than Earth's, but Pluto nevertheless has weather of a kind – the dark streaks show evidence of prevailing winds, while the tholin deposits drift down from the sky like a very light snow.

0.002 Pluto's mass in terms of Earth's mass – the icy dwarf is much less dense than our own planet

153.3 *The length of a day on Pluto in hours - that's 6.4 times longer than an Earth day*

4.67 *Pluto's mean orbital speed in km/s (0.157 times that of Earth's)*

0.06g Pluto's gravity compared to that of Earth

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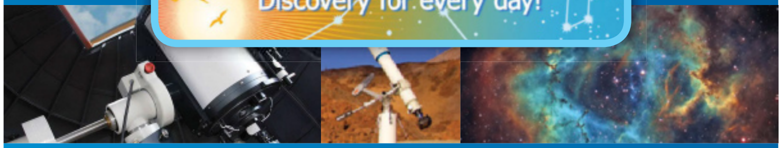

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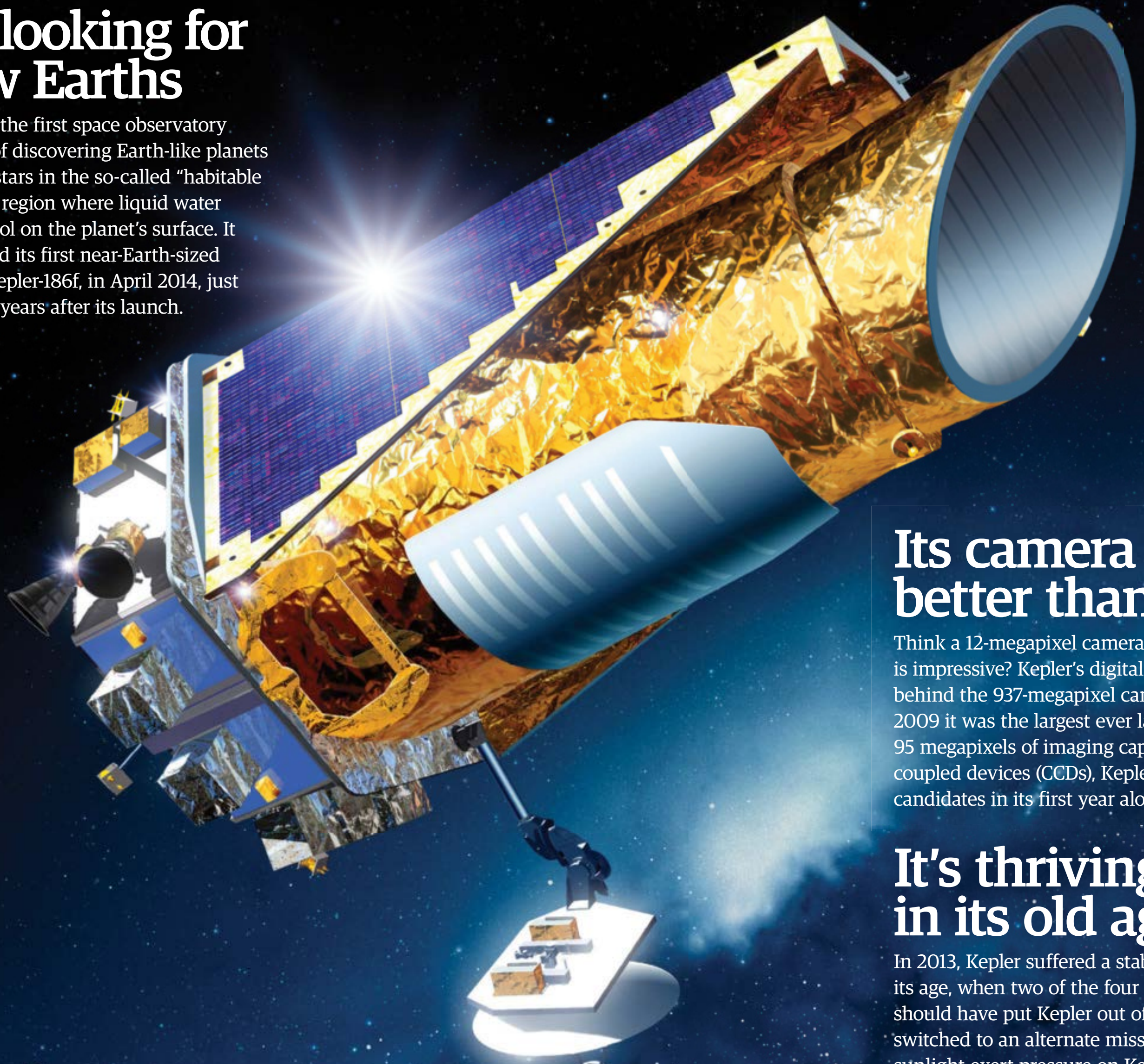
5 AMAZING FACTS ABOUT

The Kepler Space Telescope

It's looking for new Earths

Kepler is the first space observatory capable of discovering Earth-like planets orbiting stars in the so-called "habitable zone" – a region where liquid water might pool on the planet's surface. It confirmed its first near-Earth-sized planet, Kepler-186f, in April 2014, just over five years after its launch.



NASA's Kepler Space Telescope launched in 2009 and has found and verified over 1,000 new planets

It can work out if a planet is suitable for life forms

With a 0.95-metre (19.7-inch) diameter telescope, Kepler watches for regular, repeating transits of a planet passing in front of its parent star from the telescope's perspective. By noting any changes in the star's brightness, we can work out a planet's potential habitability as light shines through its atmosphere, highlighting its composition.

Its camera is better than yours

Think a 12-megapixel camera on a mobile phone is impressive? Kepler's digital camera may now lag behind the 937-megapixel camera on board Gaia, but in 2009 it was the largest ever launched into space. With 95 megapixels of imaging capacity, using 42 charge-coupled devices (CCDs), Kepler snapped 700 planet candidates in its first year alone.

It's thriving in its old age

In 2013, Kepler suffered a stabilisation problem due to its age, when two of the four reaction wheels failed. It should have put Kepler out of commission but NASA switched to an alternate mission: K2. Now, photons of sunlight exert pressure on Kepler to keep it balanced.

It's confirmed more than 1,000 planets

More than 150,000 stars beyond our Solar System have been continuously monitored and, in January 2015, NASA announced it had verified 1,000 planets observed by Kepler out of more than 4,000 candidates, including ten circumbinary planets (where exoplanets orbit two stars). As of February 2016, the number of Kepler's confirmed planets now stands at 1,035.

@ Getty Images

We're going to crash into Andromeda

+50 other out-of-this-world space facts

Written by Laura Mears

The Milky Way and the Andromeda Galaxy are moving towards each other at 400,000km/h (249,000mph) and will collide in 4.5bn years

1

Andromeda is one of our closest galactic neighbours and we're hurtling towards one another at a speed of more than 400,000 kilometres (249,000 miles) per hour. We are still 2.5 million light years away, but with the two galaxies already bound together by gravity, there's no escape.

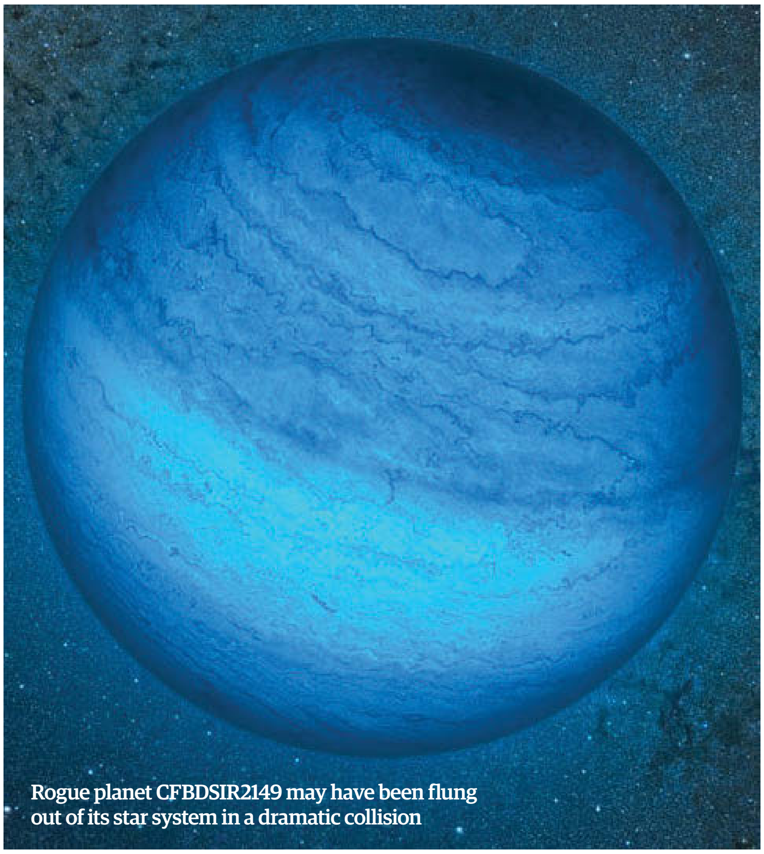
However, the situation is not as bleak as it sounds. Collisions between galaxies are commonplace in the universe, and whilst they distort the structure of galaxies, the stars and planets inside of them remain mostly unharmed. This is because there is so much space between stars that when two galaxies merge, there is still plenty of room for everyone.

We are due to collide around 4.5 billion years from now, and it will take a further 2 billion years for the galaxies to merge, but eventually, the Milky Way and Andromeda will become a massive elliptical galaxy that some people are calling 'Milkomeda'. The Sun will end up in a different position, but, aside from a different view of the night sky, nothing much should change.

2 Some planets have gone rogue

CFBDSIR2149 is a massive planet, several times the size of Jupiter, but there is something unusual about its orbit; it doesn't have one. At least, not around a star.

It was spotted by astronomers in 2012 and is known as a 'rogue planet'. It is possible that it used to be part of a star system, and was flung away from its parent in a dramatic collision, but there is a chance that it has always been a loner. Stars form when dust and gas gather together, forming a sphere dense enough to trigger nuclear fusion, but if there is not quite enough matter, this process doesn't finish. The result is a failed star, known as a brown dwarf.



Rogue planet CFBDSIR2149 may have been flung out of its star system in a dramatic collision

3 Life has 1.5 billion years left on Earth

The Sun is only half way through its life, but it is already showing signs of aging. It has been generating its power by slamming hydrogen atoms together to produce helium, and originally contained around 70 per cent hydrogen gas, but today it is down to just 35 per cent. Its fuel is running out.

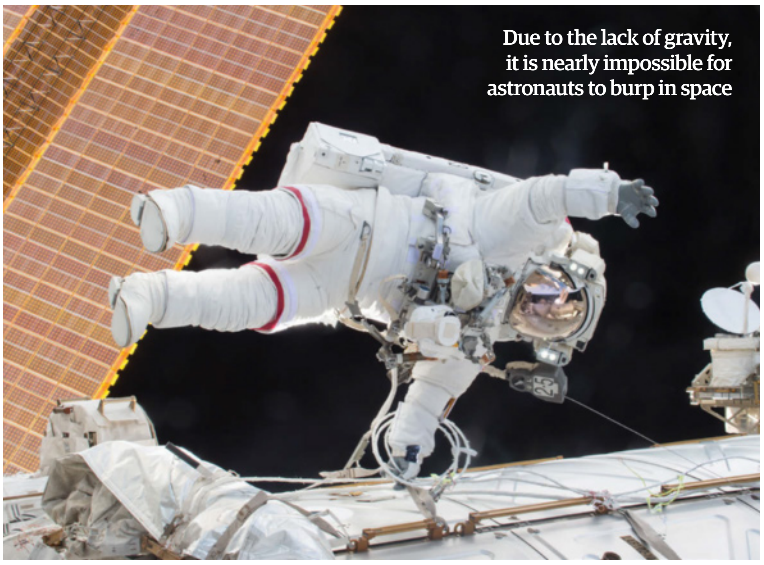
Our Sun has been burning through its energy reserves for 4.5 billion years already, and as it ages, it is gradually getting brighter. This process will be happening slowly at around six per cent every billion years, but another six per cent and the Earth will be in serious trouble.

Over the next billion years, the Sun will continue to get brighter and hotter. In turn, the Earth will get warmer, and as surface temperatures rise, water will start to evaporate, travelling up through the atmosphere before boiling away into space. The oceans will cling on longer, hopefully preserving some underwater life, but eventually our planet will be completely parched.

4 You can't burp in space

Space travel does strange things to the human body, affecting muscles, bones, circulation, balance, and much more, but one of the strangest effects of microgravity is that it makes it almost impossible to burp.

On the ground, gases rise to the top of the stomach, gathering in an area known as the fundus. From here, they can easily be expelled through the mouth. But in space, there is no 'up'. Instead of collecting in one place, swallowed gasses remain mixed with liquid and solid food. So, when an astronaut burps in space, they get much more than they bargained for.



Due to the lack of gravity, it is nearly impossible for astronauts to burp in space

5 Some TV static is from the Big Bang

Every centimetre of space contains photons from the Big Bang. You can see them as static by flicking between channels on an old analogue television.

6 Our galaxy is still making new stars

Each year, around seven new stars are born in the Milky Way galaxy. And every 50 years, one massive star explodes.

7 We are orbiting a black hole

There is a supermassive black hole at the centre of our galaxy. It is called Sagittarius A* and is 26,000 light years away.

8 The International Space Station cost $100bn

The ISS is the most expensive structure in human history at $100 billion (£70 billion), and has been permanently occupied since 2000.

9 All of the planets could fit inside Jupiter

Jupiter is so huge that all of the other planets in the Solar System could fit inside it - and there would still be room to spare!

10

NASA are reinventing the spacesuit

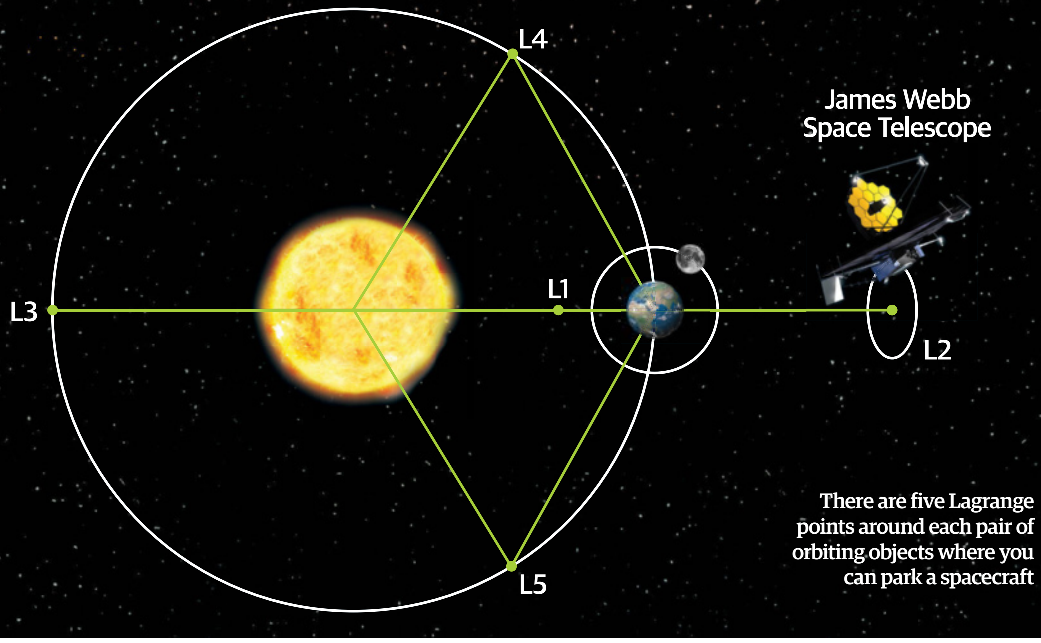
The Z-2 is still in prototype form, but it marks the biggest change to spacesuit design for decades. In preparation for future manned missions to Mars, NASA are trying something different.

The new spacesuit looks like something from a science fiction film, with colour changing electroluminescent wire and a bubble-shaped helmet. But it has not just been built for style. NASA have tried to mimic features that protect some of the most resilient species on the planet - in this case, the bioluminescent animals that inhabit the depths of the oceans.

The torso is rigid, providing protection for the upper body, and the legs have been designed to allow astronauts to move freely on the surface of alien worlds. The suit is accessed by a hatch at the back, and can be easily adjusted to fit people of different shapes and sizes.

NASA's new spacesuit mimics features that protect some of the most resilient animals on Earth

11 You can park a spacecraft in orbit



There are five Lagrange points around each pair of orbiting objects where you can park a spacecraft

Normally, when objects orbit the Earth, the Moon, or the Sun, they gradually shift out of line, moving at slightly different velocities and changing their position with respect to the ground. However, there are points in the Solar System where small objects can be parked so that they stay still. There are five of these special places around each pair of orbiting objects, and they are known as Lagrange points.

At these points, the gravitational pulls of a planet and the Sun (or a planet and its moon) interact with the orbital motion of objects like spacecraft or asteroids. This allows objects to orbit in the same relative spot, maintaining a clear view of exactly the same location on the nearby star, planet or moon. The L4 and L5 points are more stable than the other three, so much so that asteroids known as Trojans are often found parked here.

12 Buzz Lightyear has been into space

In 2008, a Buzz Lightyear toy travelled to the International Space Station and spent 15 months with the crew.

13 Apollo 13 actors really were weightless

Scenes from the movie were filmed during hundreds of parabolic flights in the 'Vomit Comet', allowing the actors to experience weightlessness.

14 Your body is warmer than some stars

Brown dwarf stars are too small to sustain nuclear fusion, and the coldest brown dwarfs have temperatures similar to the Arctic back here on Earth.

15 Pluto is smaller than the Moon

It isn't hard to see why Pluto was demoted to the status of dwarf planet. It is only about the size of the United States.

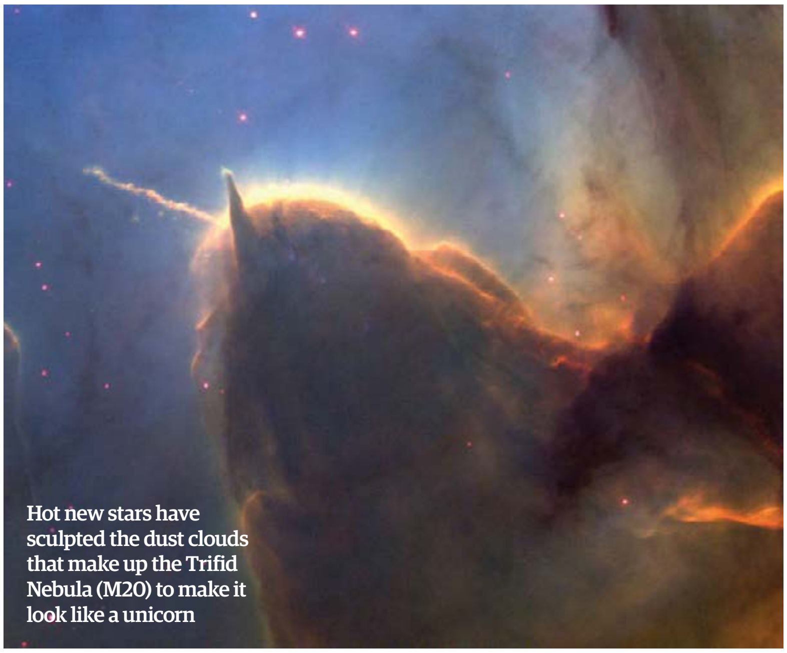
16 We've discovered over 1,900 exoplanets

And those are just the ones that have been confirmed; there are thousands of other candidates that have already been spotted.

17 There is a space unicorn

Unicorns are a human invention, but that hasn't stopped the universe making one of its own. It is found in the constellation of Sagittarius, in a region of dust and gas known as the Trifid Nebula, or M20. The nebula is just 5,000 light years away, and it can be seen with amateur telescopes during the summer months in the Northern Hemisphere.

Here, hot new stars have sculpted the dust cloud, kicking out stellar winds and blowing huge holes in the material that surrounds them. These thick dust clouds obscure visible light, producing shadowy sculptures that are illuminated at the edges. When viewed in infrared, these new stars become visible amongst the wisps of gas.

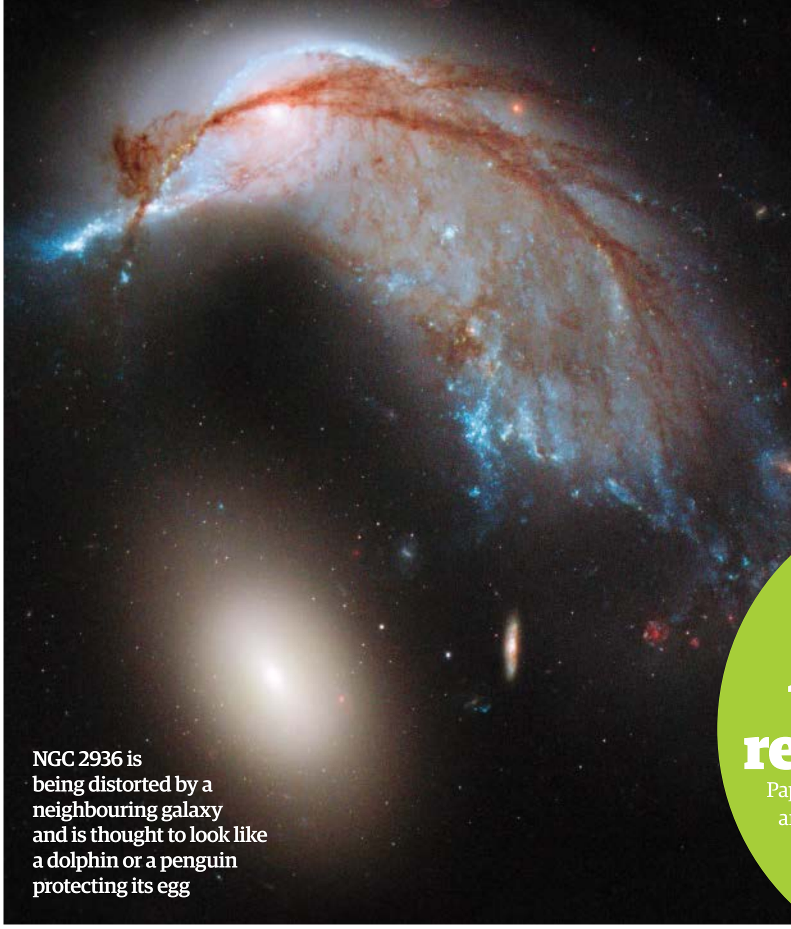


Hot new stars have sculpted the dust clouds that make up the Trifid Nebula (M20) to make it look like a unicorn

18 This galaxy looks like a penguin

Known as the porpoise galaxy, NGC 2936 used to be spiral-shaped, but it is being distorted by a neighbouring galaxy, NGC 2937 (the bright galaxy at the bottom of the image). Some people think that it looks like a dolphin, whilst others see a penguin protecting an egg.

The image was captured by the Hubble Space Telescope in 2013, and shows the dramatic results of a galactic collision in progress. When galaxies come too close, the gravitational interaction generates shock waves. These compress regions of dust and gas, triggering a chain reaction that sets off a flurry of new star formation. In this case, NGC 2936 has been twisted almost beyond recognition and, along its nose, bright blue stars have flickered into life.



NGC 2936 is being distorted by a neighbouring galaxy and is thought to look like a dolphin or a penguin protecting its egg

19 Paper folded 42 times would reach the Moon

Paper doubles in thickness with each fold and it would take just 42 folds to make a wad thick enough to stretch the 384,400 kilometres (238,855 miles) to the Moon.

20 We are inside the Sun

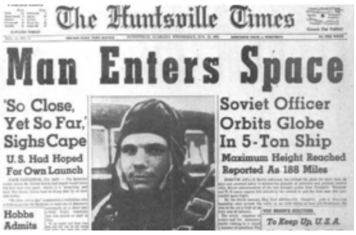
The Sun might look far away, but we are actually living inside of it. What we see from Earth is the surface of the Sun, but it has an atmosphere that balloons out for billions of kilometres (or miles), enveloping all of the planets in the Solar System. This atmosphere is known as the corona, and we are sitting right inside it.

Our planet is constantly bombarded by solar winds that whip outwards from the Sun's surface, but we are protected by the atmosphere and by Earth's magnetic field. Within this shield we are mostly safe, but some particles do get through and when they slam into the atmosphere we see the northern, or southern, lights.

The Sun's atmosphere reaches out for billions of kilometres (miles), encompassing all of the planets in our Solar System

21 Days are getting longer

The Earth's rotation is gradually slowing down - each century the Solar day lengthens by 1.4 milliseconds.



The Huntsville Times

Man Enters Space

'So Close, Yet So Far,' Sighs Cape

U.S. Had Hoped For Own Launch

Hobbs Admits

Soviet Officer Orbits Globe In 5-Ton Ship

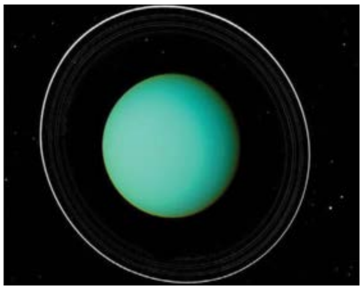
Maximum Height Reached Reported As 188 Miles

To Keep Up, U.S.A.

22 Over 500 people have been to space

The first person to venture into outer space was Russian cosmonaut Yuri Gagarin in 1961, and since his historic flight, hundreds more have followed in his footsteps. The original trip lasted just 108 minutes, but astronauts and cosmonauts now visit the International Space Station for trips lasting months at a time. Together, they have clocked up more than 125 years away from Earth.

The first woman in space was also a Russian cosmonaut, Valentina Tereshkova, but so far no children have been up there. In fact, the youngest person to fly to space so far was Gherman Titov, another Russian, who was just 25 years old at the time. The oldest was American astronaut John Glenn, aged 77.



23 Saturn isn't the only planet with rings

Saturn might be famous for its planetary rings, but it is not the only one. In fact, all of the gas giants in the Solar System have them, and so do a number of planets orbiting other stars. But not all rings are created equal.

Saturn's impressive rings span 282,000 kilometres (175,200 miles) and are made from chunks of ice, most of which are smaller than a tennis ball. Jupiter's faint and dusty rings are possibly made from the scattered remains of asteroid impacts. Uranus has rings of dark, dirty ice, and Neptune's are thought to be ice and rock.

24 Space whisky tastes different

When whisky is matured in space, it tastes smokier than when it is made here on Earth. This is perhaps due to changes in the way the molecules behave.

25 Space travel blocks your nose

Our circulatory system normally works against gravity, but in space, fluids are not pulled towards the feet. This means that extra fluid in the face causes a runny nose.

26 Flames are round in space

In the microgravity of space, flames burn slow, round and blue, and if conditions are right, they produce no soot at all.

27 Mercury isn't the hottest planet

Venus has a thick atmosphere filled with greenhouse gases, and is around 40 degrees Celsius (72 degrees Fahrenheit) hotter than Mercury's maximum temperature.

28 We take 240 million years to orbit the galaxy

We orbit the centre of the galaxy at a speed of 828,000 kilometres (514,500 miles) per hour. One orbit takes around 240 million years.

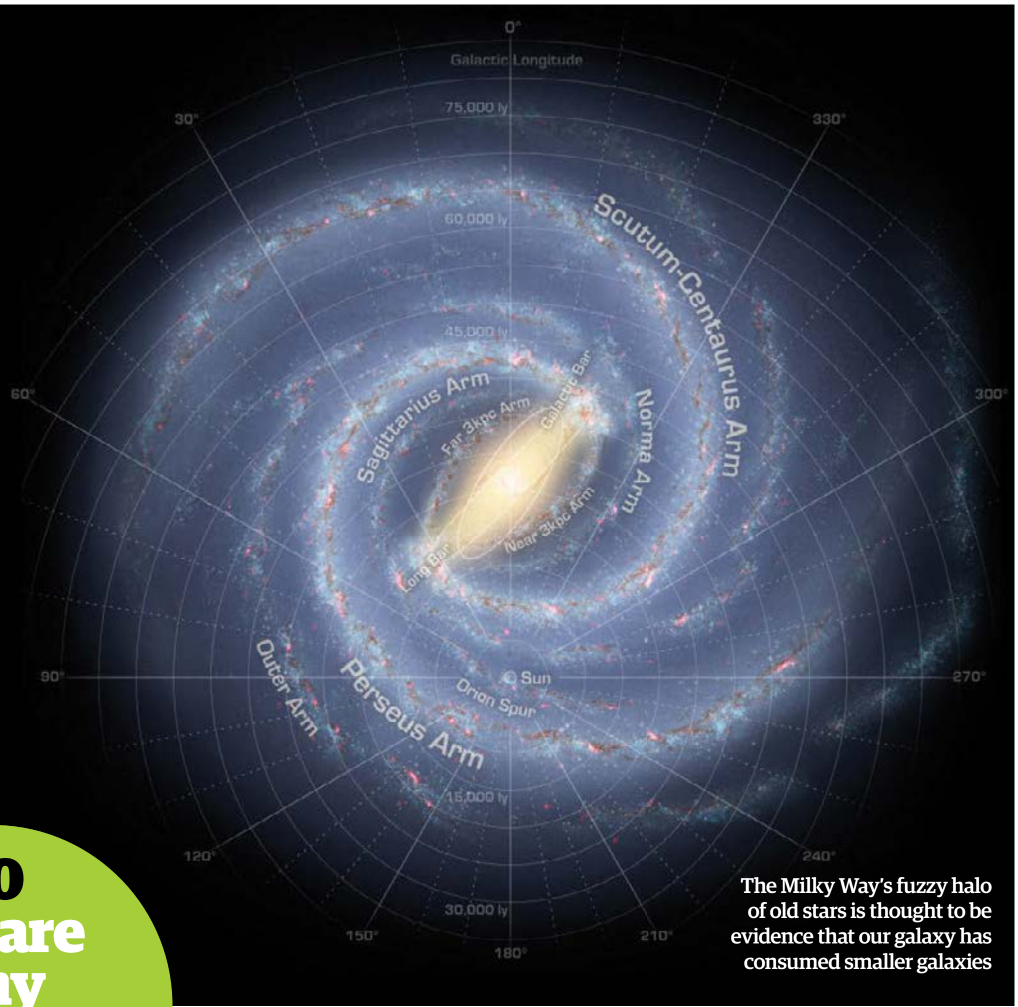
29

Our galaxy is a cannibal

The Milky Way might look like a fairly unassuming spiral galaxy, but it has a dark past. Like many other galaxies, it is likely to have ripped smaller galaxies apart and stolen their stars.

If you looked at the Milky Way side on, it would be thin and flat, with a bulge of older, yellower stars in the middle. Some of these stars don't seem to belong. They have a much lower metal content than the other stars in the galaxy, indicating that they were formed earlier in the history of the universe.

Scientists think that the fuzzy halo of old stars is evidence that the Milky Way has been snacking on smaller dwarf galaxies, capturing them in its gravitational pull and then gradually pulling them apart.



The Milky Way's fuzzy halo of old stars is thought to be evidence that our galaxy has consumed smaller galaxies

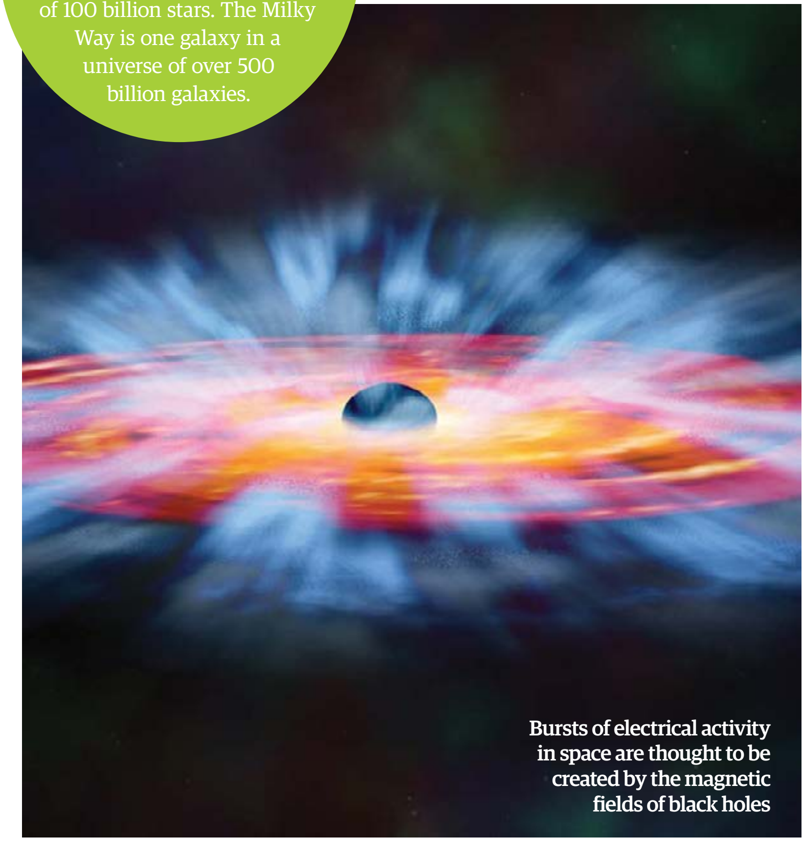
30 We are tiny

The Sun is one star in a galaxy of 100 billion stars. The Milky Way is one galaxy in a universe of over 500 billion galaxies.

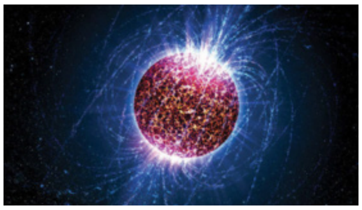
31 There's electricity in space

Lightning is a familiar sight on Earth, the ground is struck around 100 times every second worldwide, and even Saturn and Jupiter have their own storms, but you might be surprised to know that there is electricity out in the depths of space. The largest space current discovered so far measures one quintillion amps (10,000,000,000,000,000,000 amps) - bearing in mind that a lightning bolt on Earth is 5,000 to 20,000 amps.

Our lightning is generated by differences in electrical charge that build up when hot and cold air rush past each other in the atmosphere, but the origin of this incredible burst of electrical activity is thought to be a black hole. These massive objects produce intense magnetic fields, and magnetic fields induce powerful electrical currents.



Bursts of electrical activity in space are thought to be created by the magnetic fields of black holes



32 One star spins 716 times a second

Neutron stars are the compacted remnants of massive stars that have run out of fuel. As the dying star crunches down under its own gravity, atoms are crushed together, causing protons and electrons to fuse, leaving behind a sphere of tightly packed neutrons. Just as a ballet dancer spins faster when they bring their arms in, stars spin faster when they collapse.

The Sun takes 27 days to turn once on its axis, but a neutron star has much more matter crammed into a much smaller space, so it rotates several times every second. The fastest neutron star spins an incredible 716 times a second; beyond what was once thought possible.

33 There is alcohol in space

In 2006, the MERLIN telescopes at Jodrell Bank detected a strange cloud of methyl alcohol surrounding newly forming stars.

34 It is more than four light years to the nearest star

Our closest stellar neighbour, Proxima Centauri, is more than 39,900,000,000,000 kilometres (24,800,000,000,000 miles) away.

35 Birds can't cope with space

Lots of animals have made the trip into space, but birds can't swallow without gravity.

36 Venus has the longest days

Of all the planets in the Solar System, Venus has the longest day, lasting 5,832 hours.

37 Space is silent

Sound travels by vibration, and without any molecules to vibrate, it cannot get far in a vacuum.

38 There are diamond planets

55 Cancri e is thought to be composed of diamond, and it has an estimated value of $26.9 nonillion (that's 26.9 followed by 30 zeros!) .

NASA's New Horizons launched at 45km/s (28mi/s) making it the fastest spacecraft to date

39 New Horizons is the fastest spacecraft to date

At least, it had the speediest launch. The piano-sized spacecraft left Earth bound for Pluto in 2006 at a mind-bending 45 kilometres (28 miles) per second. Under the influence of the Sun's gravity, it gradually slowed on its journey towards the outer Solar System, but when it passed Jupiter, it used the massive planet for a boost.

For the top speed during a mission, NASA's Juno probe might be about to take the title. It is on its way to Jupiter, and during its final approach it will reach speeds of around 73 kilometres (46 miles) per second.

With a thicker atmosphere and lower gravity than Earth, humans would be able to fly on Saturn's moon, Titan

40

We could fly in Titan's atmosphere

Saturn's moon, Titan, has a thicker atmosphere and lower gravity than Earth, and in theory, a human should be able to fly above the surface. Every square metre of atmosphere on Titan is around seven times more massive than the equivalent area of atmosphere back on Earth, packing more molecules into the same space. With more to push against, even a human should be able to get airborne.

Students at the University of Leicester calculated that, with a normal wingsuit, you would need to run at a speed of 11 metres (36 feet) per second to take off – just a little slower than the top speed of Earth's fastest runner, Usain Bolt. With larger wings, this take-off speed could be halved. But don't get too excited, Titan has no oxygen and temperatures are a chilly -178 degrees Celsius (-288 degrees Fahrenheit).

41 The Moon is getting further away

The radius of the Moon's orbit is increasing, but it's happening slowly, at a rate of about 3.8 centimetres (1.5 inches) each year.

42 The first chimp in space was called Ham

Astrochimp, Ham launched in 1961 and was weightless for six and a half minutes before returning safely to Earth.

43 Only 12 people have walked on the Moon

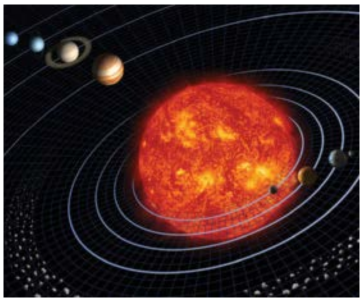
Humanity first visited the Moon almost 50 years ago, but no one has been back to the lunar surface since 1972.

44 The Milky Way tastes like rum

The gas cloud at the centre of the Milky Way contains ethyl formate, a chemical that is found in rum and raspberries.

45 Nixon wrote an Apollo failure speech

In case the Moon landing failed, he wrote, "The men who went to the Moon to explore in peace will stay on the Moon to rest in peace."

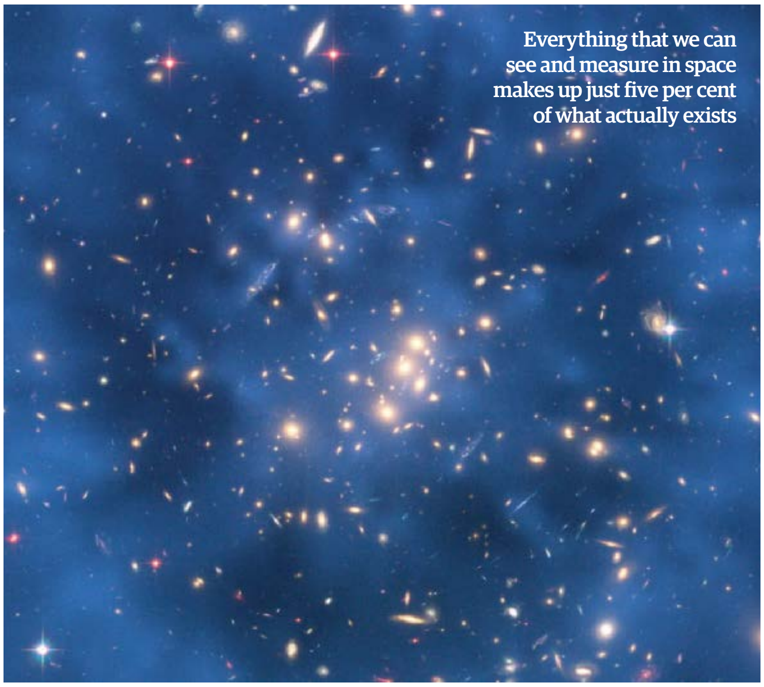


46 There is a planet missing

The planets in our Solar System might look pretty normal to us, but when compared to the arrangement around other stars, our situation looks a little bit strange. The inner four planets - Mercury, Venus, Earth, and Mars - are small and rocky, whilst the outer four - Jupiter, Saturn, Uranus and Neptune - are massive and gassy.

When we look out at other star systems, the most commonly spotted exoplanets are somewhere between Earth and Neptune; middle-sized rocky planets surrounded by gas. Here in the Solar System, we don't have any.

Scientists now believe that, when the Solar System was in its infancy, the gas giants were much closer to the Sun, and there may have been more planets than we see today. Suggestions include a fifth gas giant between Saturn and Uranus that was ejected during a clash with Jupiter, a fifth rocky planet between Mars and Jupiter that met a similar fate, or a super-Earth that Jupiter devoured.



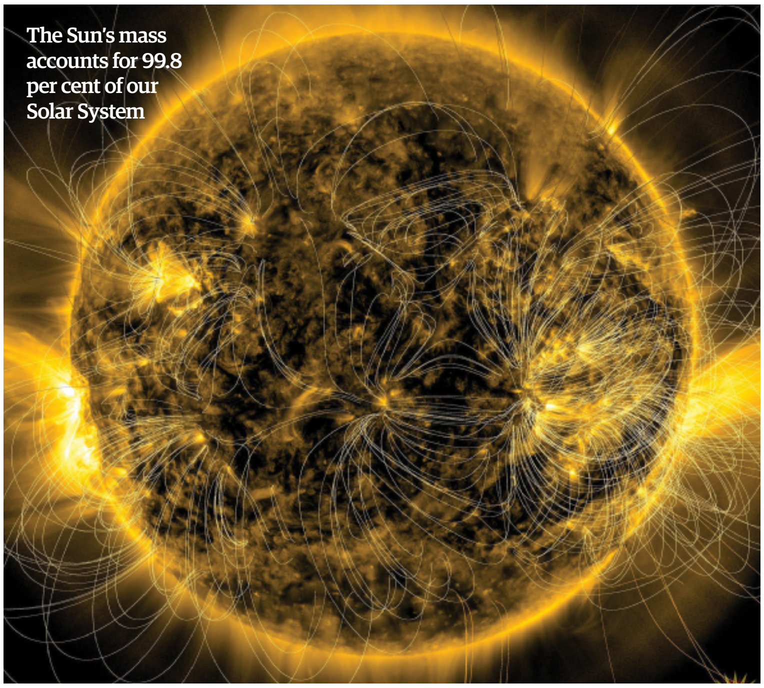
Everything that we can see and measure in space makes up just five per cent of what actually exists

47 95 per cent of the universe is unknown

All of the things that we can see and measure in space make up less than five per cent of what is actually there; the other 95 per cent is a mystery, and we don't even know how to detect it.

When astronomers examined the stars orbiting the centres of galaxies, they found that the ones at the outer edges were moving too fast. The matter we can see doesn't produce a gravitational field strong enough to hold everything together, so there must be something else. This has been named 'dark matter', and accounts for 23 per cent of the missing universe.

The remainder has been dubbed 'dark energy' and, like dark matter, we know it is there because we can see what it is doing. The universe began with an explosion and it is still expanding outwards, but rather than slowing down, or maintaining a steady speed, it is speeding up. Dark energy is opposing gravity.



The Sun's mass accounts for 99.8 per cent of our Solar System

48 The Sun makes up 99.8 per cent of the Solar System

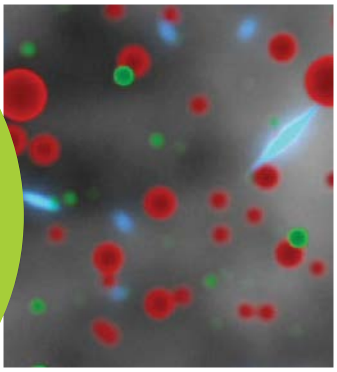
Our star, Sol, is a 4.5-billion-year-old yellow dwarf. It is not particularly massive compared to other stars, but in comparison with the rest of the Solar System it is huge.

If you add up the matter from all of the planets, moons, asteroids, comets and other objects, they only account for around 0.2 per cent of the mass in the Solar System - all of the rest belongs to the Sun. It takes up over a million times more volume than Earth, and is made up of mostly hydrogen and helium, the two lightest elements in the universe.

49

You can see the back of a neutron star from the front of it

The gravitational pull of a neutron star is so intense that light bends as it passes, allowing you to see some of the back of the star from the front of it.



50 Sunlight is thousands of years old

Light only takes eight minutes to travel from the Sun to Earth, but it was produced in reactions that happened thousands of years ago. The Sun is a nuclear reactor and light is released every time atoms smash together at its core, but it can take a surprisingly long time for it to escape the surface and start its journey towards the Earth.

Photons of light will travel in a straight line until they hit something, but there are so many particles inside the Sun that each one can only make it a short distance before they change direction. In the core of the Sun, the distance is around 0.01 centimetres (0.004 inches), and out at the edges, this rises to around 0.3 centimetres (0.1 inches). With all of this chopping and changing, it takes each photon tens, or even hundreds, of thousands of years to get out of the maze.

It is likely that Neil Armstrong's footprint will remain on the lunar surface for thousands of years

51 Armstrong's footprints are still on the Moon

The Moon landing was a historic moment and the evidence will remain preserved for millennia. The Moon is coated in a thick layer of very fine dust, formed from the remnants of thousands upon thousands of rocks that have crashed into its surface. When Neil Armstrong stepped down from the Apollo 11 lander, he planted his foot in this soft, ash-like powder, leaving a near perfect boot print.

In the Moon's low gravity conditions, the print will not collapse under its own weight like it might do on Earth, and without any wind to blow the particles away, it is likely to remain visible for thousands of years - unless, of course, we go back and disturb it.

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Space elevator

Launching into space is a hazardous process. Wouldn't it be simpler if we could take a lift?

A space elevator is the idea of building a lift connecting the ground to Earth orbit. The first person to consider it was Konstantin Tsiolkovsky (who was the first to set out the equations that govern orbital rocket launches), in 1895 he was inspired by the new Eiffel Tower to point out that if such a tower could be built 35,800 kilometres (22,245 miles) tall, you could go to space just by taking the lift up the tower. To appreciate why (and why 35,800 kilometres or 22,245 miles) we must consider how orbits work.

When spacecraft launch into space they don't just pass out of the atmosphere and start floating. Getting past the atmosphere is fairly easy; the boundary of space is only 100 kilometres (62 miles) up. To be in orbit, a craft has to be travelling fast enough horizontally (eight kilometres/five miles per second) that the tendency to be flung away from Earth is

Riding the elevator

The tether provides a physical link for the climbers to journey into space. Most likely the tether will be a ribbon shape and the climbers will simply clamp on and drive up it with rollers. Power could be provided through a carbon tether from solar panels on the counterweight, or carry solar panels lit by ground based lasers. The climbers would travel at about 200km/h (124mph), taking 7.5 days to reach GEO, making for a very different launch experience.

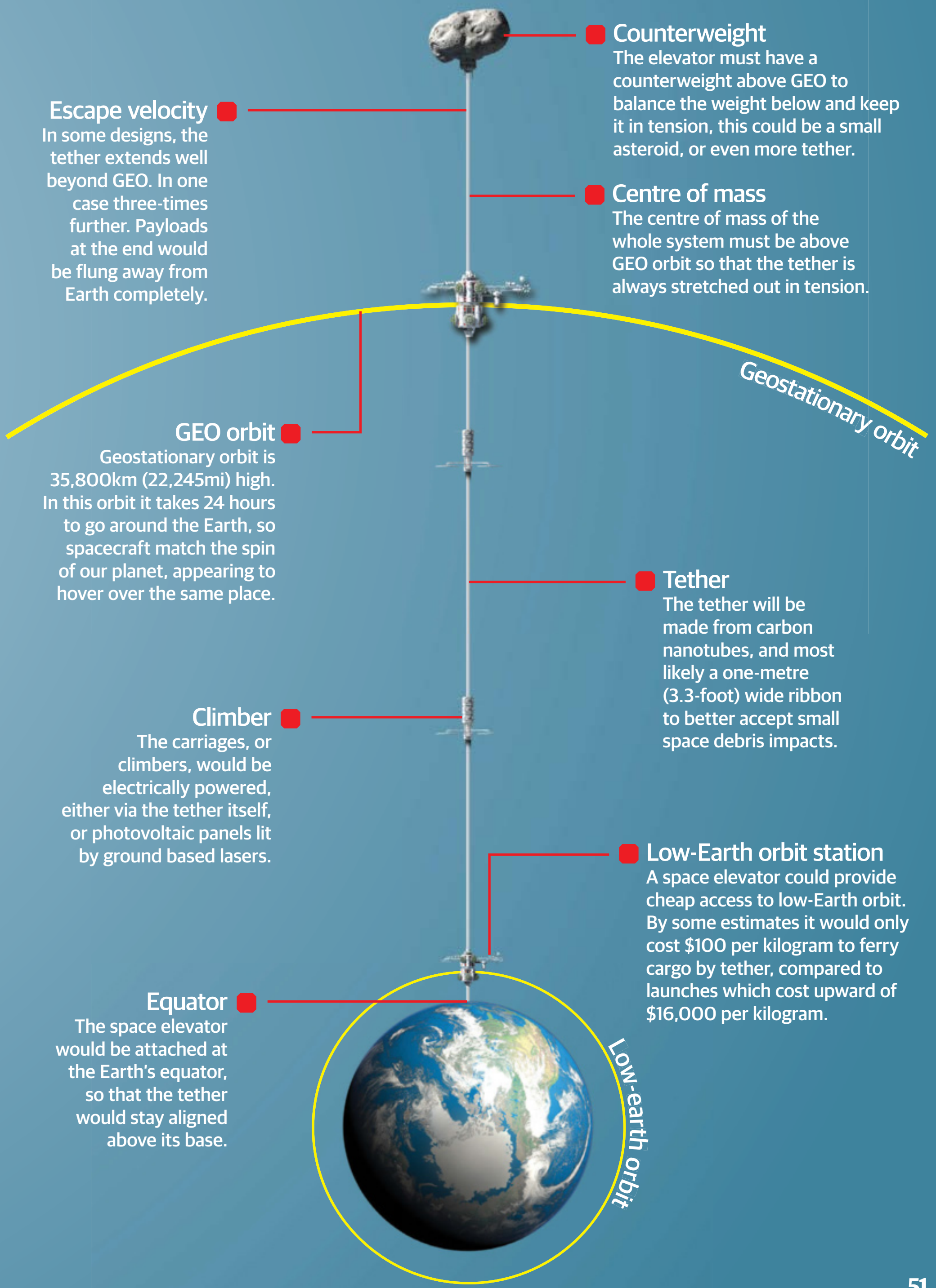
balanced by the gravity trying to pull it back down, so that it continuously circles Earth. The higher the orbit, the faster the spacecraft must travel, and the longer it takes to orbit; 35,800 kilometres (22,245 miles) high is an orbit called "geostationary" (GEO). In GEO it takes 24 hours to make one orbit, so spacecraft appear to hover over the same spot on Earth - this is used for satellite TV so you get continuous signal.

Travelling on a space elevator, you would slowly gain both the height and speed required to be in GEO at the top. There would be no violent launch, or highly stressed rocket engines, just electric motors gently lifting you into space over the course of a few days (it is the same as taking a train 90 per cent of the distance around the world). But we can't build a tower that tall; no material comes close to supporting its own weight at such a height, but in 1959 another Russian scientist, Yuri Artsutanov, suggested that it might be possible to build such a structure if it was a cable in tension, rather than a tower in compression.

In this case, a satellite is deployed in GEO and begins to wind a tether downwards, while another tether winds outwards with a counterweight on the end. Ultimately, the first tether touches down on Earth where it can be anchored while the counterweight, being flung outwards by the rotation of the system, balances the weight of the tether, plus some spare capacity for the weight of the elevator cars (climbers) moving on it. The concept was considered science fiction for many years, though, as no materials came close to the strength needed. That changed in the 1990s with the discovery of carbon nanotubes; cylindrical molecules of carbon that would be strong enough, if we can make them long enough. A NASA study from 2000 proposed that a small 20-ton nanotube tether could be launched and installed from GEO. It would be anchored to a floating platform and then small robotic climbers would run up adding more material. This would build a one-metre (3.3-foot) wide tether, thinner than a sheet of paper but still extremely capable of lifting 20-ton climbers.

Unfortunately, no one has made nanotubes longer than 50 centimetres (19.7 inches). But, a number of organisations are working towards Space Elevators. LiftPort Group in the US are developing a commercial carbon nanotube business in support of their plans, and intend to build a space elevator headed for the Moon with existing materials by 2020. So, we may even see a railway to the sky before the second half of this century. ●

> "There would be no violent launch, just electric motors gently lifting you into space"



Counterweight
The elevator must have a counterweight above GEO to balance the weight below and keep it in tension, this could be a small asteroid, or even more tether.

Escape velocity
In some designs, the tether extends well beyond GEO. In one case three-times further. Payloads at the end would be flung away from Earth completely.

Centre of mass
The centre of mass of the whole system must be above GEO orbit so that the tether is always stretched out in tension.

GEO orbit
Geostationary orbit is 35,800km (22,245mi) high. In this orbit it takes 24 hours to go around the Earth, so spacecraft match the spin of our planet, appearing to hover over the same place.

Tether
The tether will be made from carbon nanotubes, and most likely a one-metre (3.3-foot) wide ribbon to better accept small space debris impacts.

Climber
The carriages, or climbers, would be electrically powered, either via the tether itself, or photovoltaic panels lit by ground based lasers.

Low-Earth orbit station
A space elevator could provide cheap access to low-Earth orbit. By some estimates it would only cost $100 per kilogram to ferry cargo by tether, compared to launches which cost upward of $16,000 per kilogram.

Equator
The space elevator would be attached at the Earth's equator, so that the tether would stay aligned above its base.

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SUPER VENUS

What can we learn from the planets that are bigger, badder and hotter than Earth?

Written by Jonathan O'Callaghan

As we continue to find more and more planets outside of the Solar System, one thing is becoming very obvious: there are a vast array of planets, of all sizes and orbits. We've found super-Earths, rocky planets bigger than Earth in habitable orbits, and hot Jupiters, gas giants in tight orbits. And now a new class of planet is coming to the fore: the super-Venus.

Finding out exactly how common the array of planets in our Solar System might be has been one of the key questions for planet hunters so far. We have four relatively Earth-sized terrestrial planets, and four gas giants. But our closest planet to the Sun is Mercury, which orbits the Sun at about a third of the distance that Earth does. That, as it turns out, seems rather unusual. We are finding that many planetary systems have worlds in very tight orbits, a fraction of Mercury's, with years lasting just a matter of days. These worlds are extremely hot, owing to their proximity to their star, and almost certainly uninhabitable to any life as we know it. Most of the worlds discovered so far have either been Earth-sized, or as big as gas giants like Jupiter. But that all changed in 2013 with the discovery of the first super-Earth in such a close orbit – suggesting the world was not really a super-Earth, but a super-Venus.

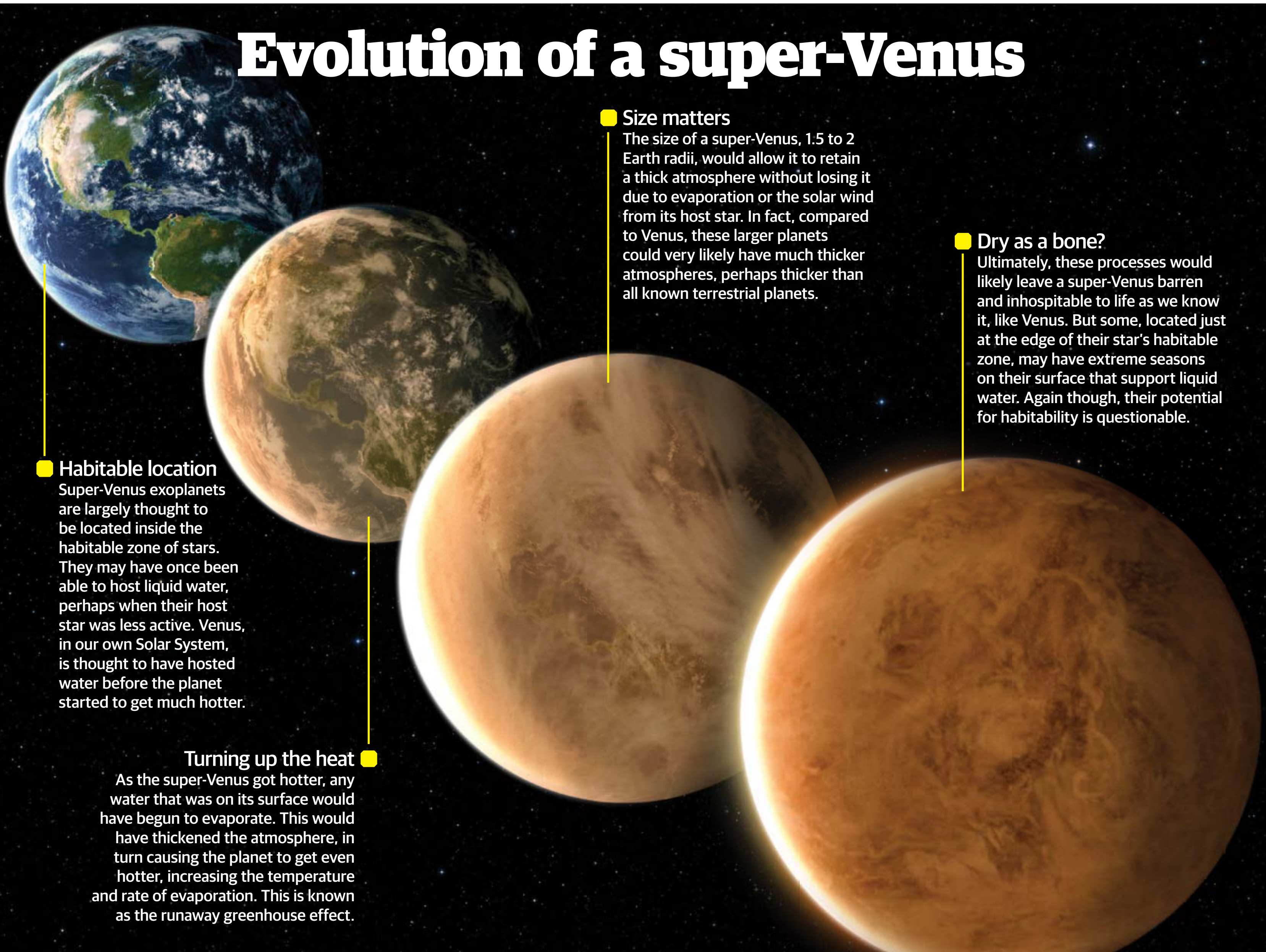
As the name suggests, these are large worlds – bigger than Earth, up to around twice the size – with atmospheric conditions that resemble the hottest planet in our Solar System, rather than the only one we know to have life. Owing to the size and the gravity of the planet, they are able to support huge atmospheres that can trap a large amount of heat. It is possible they went through runaway greenhouse effects similar to Venus in our Solar System, but on an extreme scale.

"The distinction between a super-Venus or a super-Earth signifies the location of the planet relative to its host star, and thus a measure of the expected temperature of the planet," Charles Beichman, executive director of NASA's Exoplanet Science Institute, tells **All About Space**. "Venus, being closer to our Sun than Earth, receives much more energy than Earth and thus has a hotter temperature, an effect added to by the extreme runaway greenhouse effect from Venus' thick atmosphere."

One such example is Gliese 1132b, which orbits its host star in a mere 1.6 days. Its relative proximity to Earth of 39 light years, though, led University of Maryland astrophysicist Drake Deming to say it was "arguably the most important planet ever found outside of the Solar System". The planet has an estimated average temperature of 230 degrees Celsius (440 degrees Fahrenheit), and is thought to be tidally locked – with one hemisphere always facing the Sun. At 1.2 times the size and 1.6 times the mass of Earth,

> "Its proximity to Earth makes Gliese 1132b the most important planet ever found outside of the Solar System" **Dr Drake Deming**

Evolution of a super-Venus



Habitable location
Super-Venus exoplanets are largely thought to be located inside the habitable zone of stars. They may have once been able to host liquid water, perhaps when their host star was less active. Venus, in our own Solar System, is thought to have hosted water before the planet started to get much hotter.

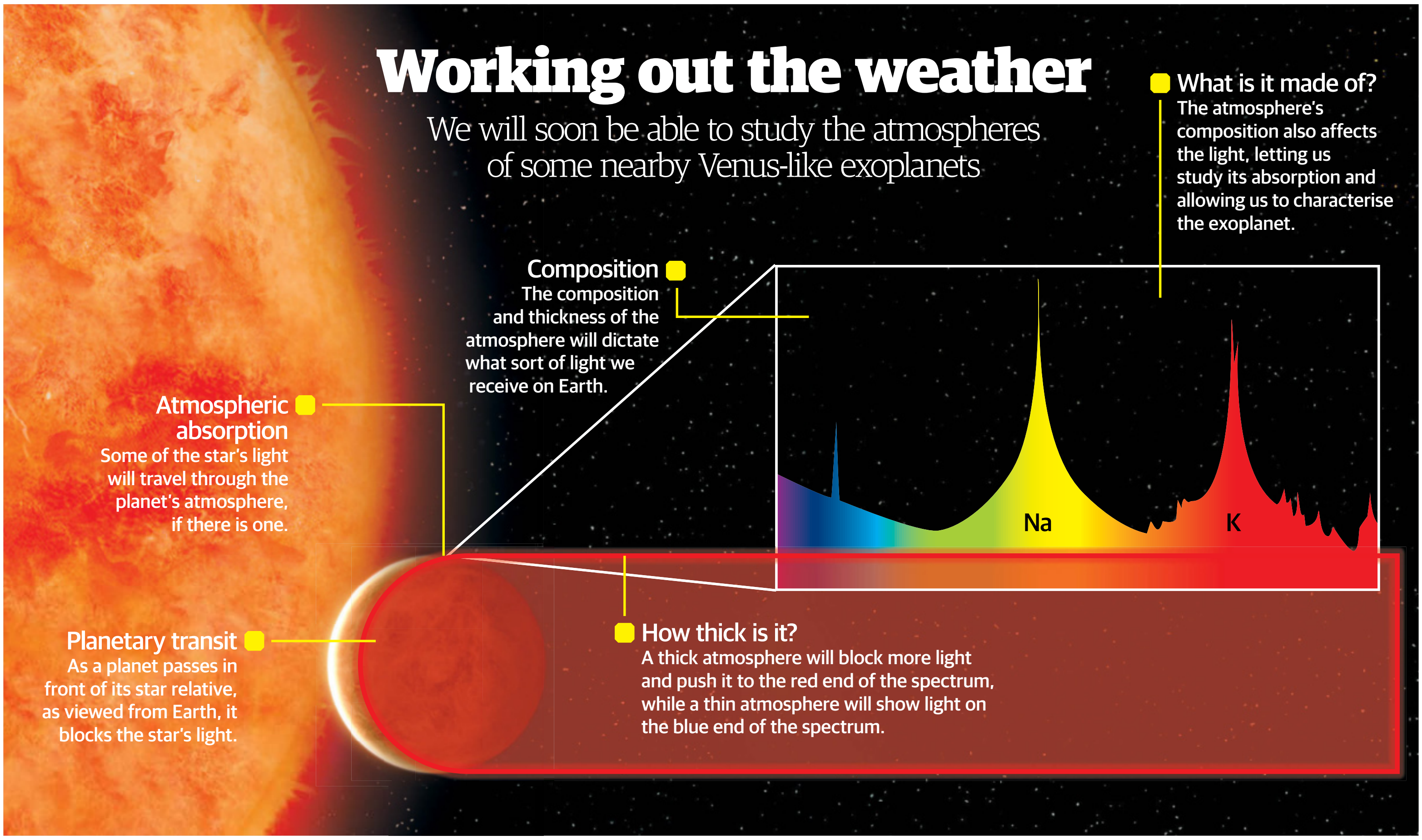
Turning up the heat
As the super-Venus got hotter, any water that was on its surface would have begun to evaporate. This would have thickened the atmosphere, in turn causing the planet to get even hotter, increasing the temperature and rate of evaporation. This is known as the runaway greenhouse effect.

Size matters
The size of a super-Venus, 1.5 to 2 Earth radii, would allow it to retain a thick atmosphere without losing it due to evaporation or the solar wind from its host star. In fact, compared to Venus, these larger planets could very likely have much thicker atmospheres, perhaps thicker than all known terrestrial planets.

Dry as a bone?
Ultimately, these processes would likely leave a super-Venus barren and inhospitable to life as we know it, like Venus. But some, located just at the edge of their star's habitable zone, may have extreme seasons on their surface that support liquid water. Again though, their potential for habitability is questionable.

Working out the weather

We will soon be able to study the atmospheres of some nearby Venus-like exoplanets



Atmospheric absorption
Some of the star's light will travel through the planet's atmosphere, if there is one.

Planetary transit
As a planet passes in front of its star relative, as viewed from Earth, it blocks the star's light.

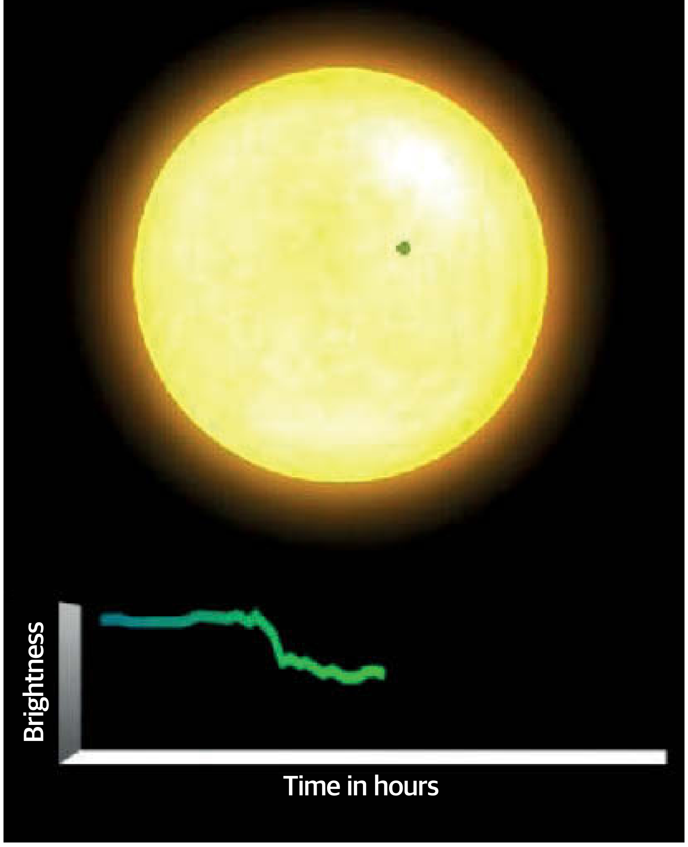
Composition
The composition and thickness of the atmosphere will dictate what sort of light we receive on Earth.

How thick is it?
A thick atmosphere will block more light and push it to the red end of the spectrum, while a thin atmosphere will show light on the blue end of the spectrum.

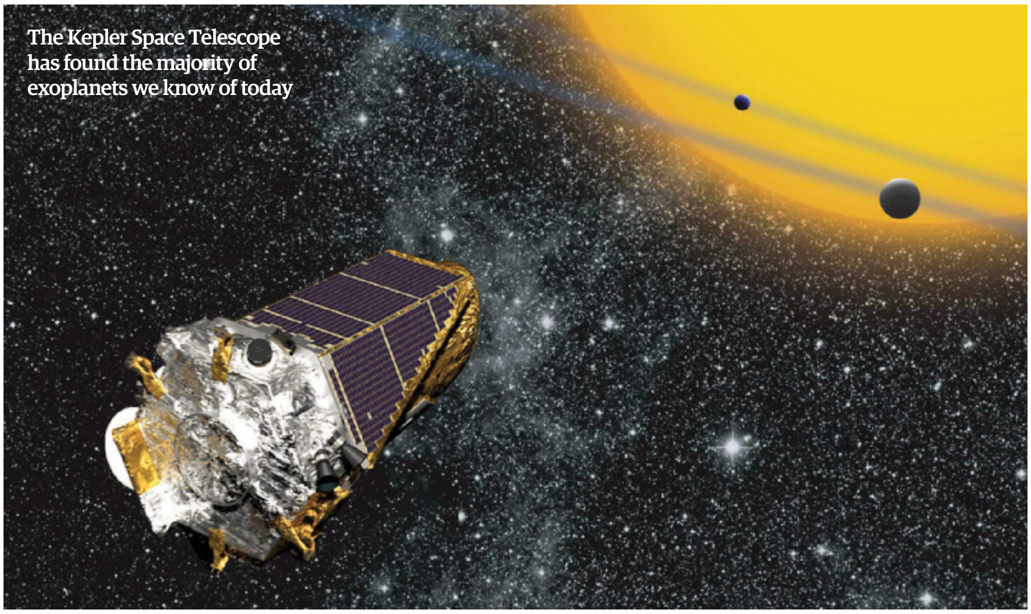
What is it made of?
The atmosphere's composition also affects the light, letting us study its absorption and allowing us to characterise the exoplanet.

Worlds close to their host star can be extremely hot

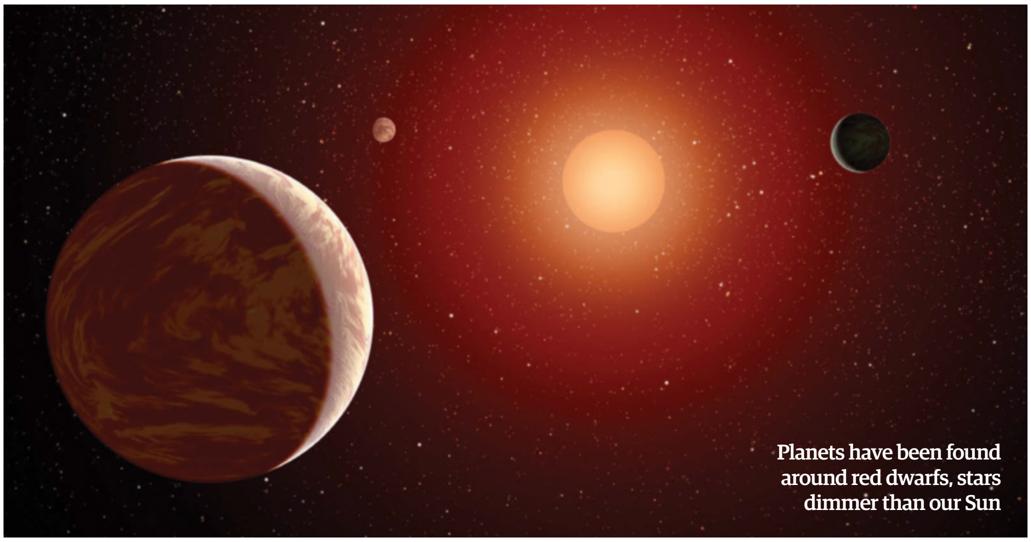
The thickness of a planet's atmosphere can be identified during its 'transit' across the face of its parent star



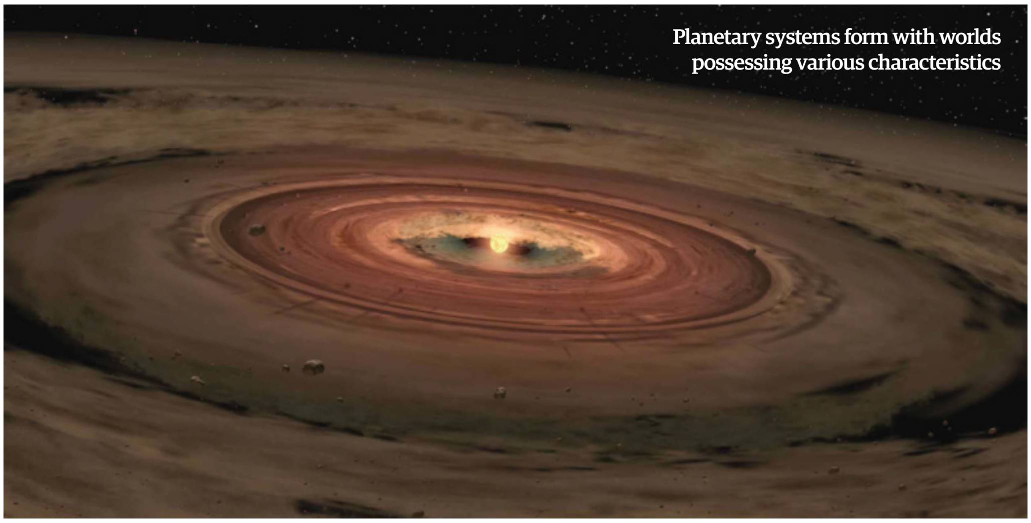
“Venus may have had liquid water on its surface 4 billion years ago when the Sun emitted 25 per cent less light”



The Kepler Space Telescope has found the majority of exoplanets we know of today



Planets have been found around red dwarfs, stars dimmer than our Sun



Planetary systems form with worlds possessing various characteristics

any atmosphere it retains is likely to be thick, giving it this high temperature. But its proximity could allow it to be studied in greater detail to learn more about these super-Venus worlds. Planets in tight orbits like this allow us to make frequent observations as they transit their star relative to Earth.

This isn't the only way super-Venus exoplanets can form though. Scientists believe that large terrestrial worlds located just within their star's habitable zone can also evolve to have extreme temperatures. While these worlds wouldn't receive a huge amount of sunlight, their thick atmospheres would trap any heat that came their way, roasting their surface and mimicking conditions on Venus in our Solar System.

One such world that has been discovered, Gliese 832c, orbits its host red dwarf star every 36 days. Located just 16 light years from Earth, it is a prime candidate for further study. As red dwarfs are considerably dimmer than our Sun, it receives a similar amount of sunlight to Earth, but with a radius 1.6 times that of Earth and a mass five-times greater, it has almost certainly accumulated a huge atmosphere over time, causing it to trap a large amount of heat.

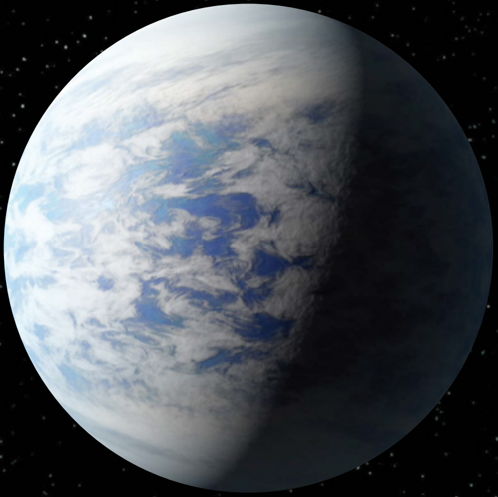
Another super-Venus, named Kepler 69c, was discovered and announced by NASA in 2013. At 1.7 times the size of Earth and orbiting just within its star's habitable zone, it could possibly have similar conditions to Gliese 832c. Originally, some had speculated this world would be Earth-like, with liquid water on the surface. Now, we're fairly certain it's more like a super-Venus. Perhaps this world more than any other, though, shows the ambiguity between worlds like our own and worlds like Venus. We don't fully understand what causes a planet to go one-way or the other and studying planets like this in more depth could provide the answer.

In our own Solar System, it's thought that Venus may have had liquid water on its surface about 4 billion years ago, during the Archean Eon, when the Sun emitted up to 25 per cent less light for reasons that are poorly understood. But when the Sun started to reach its current level of activity, it warmed the surface of Venus and evaporated some of the water in the oceans, causing the atmosphere to get thicker and, in turn, heat the planet further. The result was a runaway greenhouse effect, leading to the extremely hot and barren world we see today, which retains an extremely thick atmosphere.

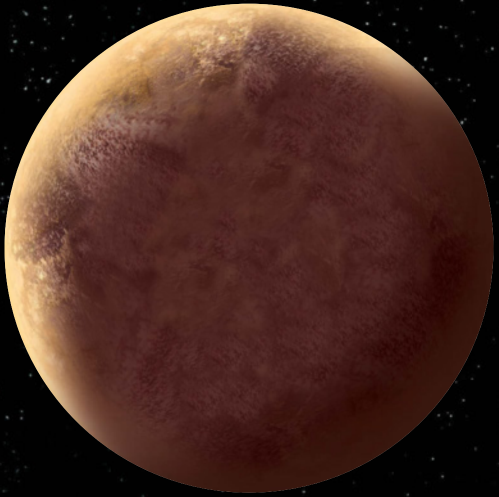
The super-Venus is a relatively new class of exoplanet, so there is still a lot we do not know about them. But there is one thing we can make a good guess at, and that is the size of their atmosphere. Larger than Earth, but having gone through the same or similar processes to Venus, they could likely support vast atmospheres thicker than anything we have seen on any terrestrial planets and feature extremely high surface temperatures. For example, super-Venus Gliese 1132b boasts an estimated surface temperature of 230 degrees Celsius (440 degrees Fahrenheit). But a planet that is too hot, for example several thousands of degrees, is not thought to be able to hold onto an atmosphere for long.

Our methods of studying super-Venus planets are limited at the moment, but in the coming years a new array of telescopes on the ground and in space – including the James Webb Space Telescope – will

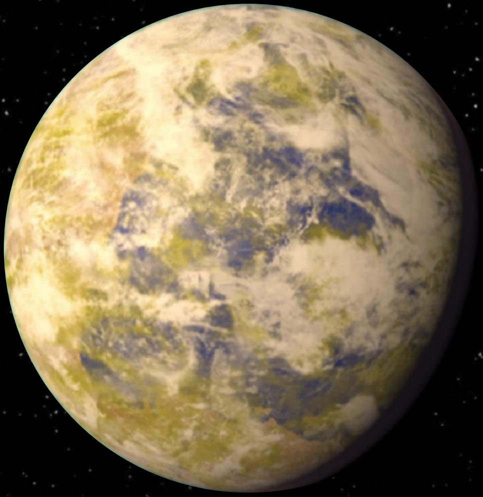
Super-Venus candidates



Kepler 69c
Parent star: Kepler 69
Distance (in light years): 1,930
Size (in Earths): 1.7
Estimate temperature: Unknown
Discovered by: Kepler Space Telescope

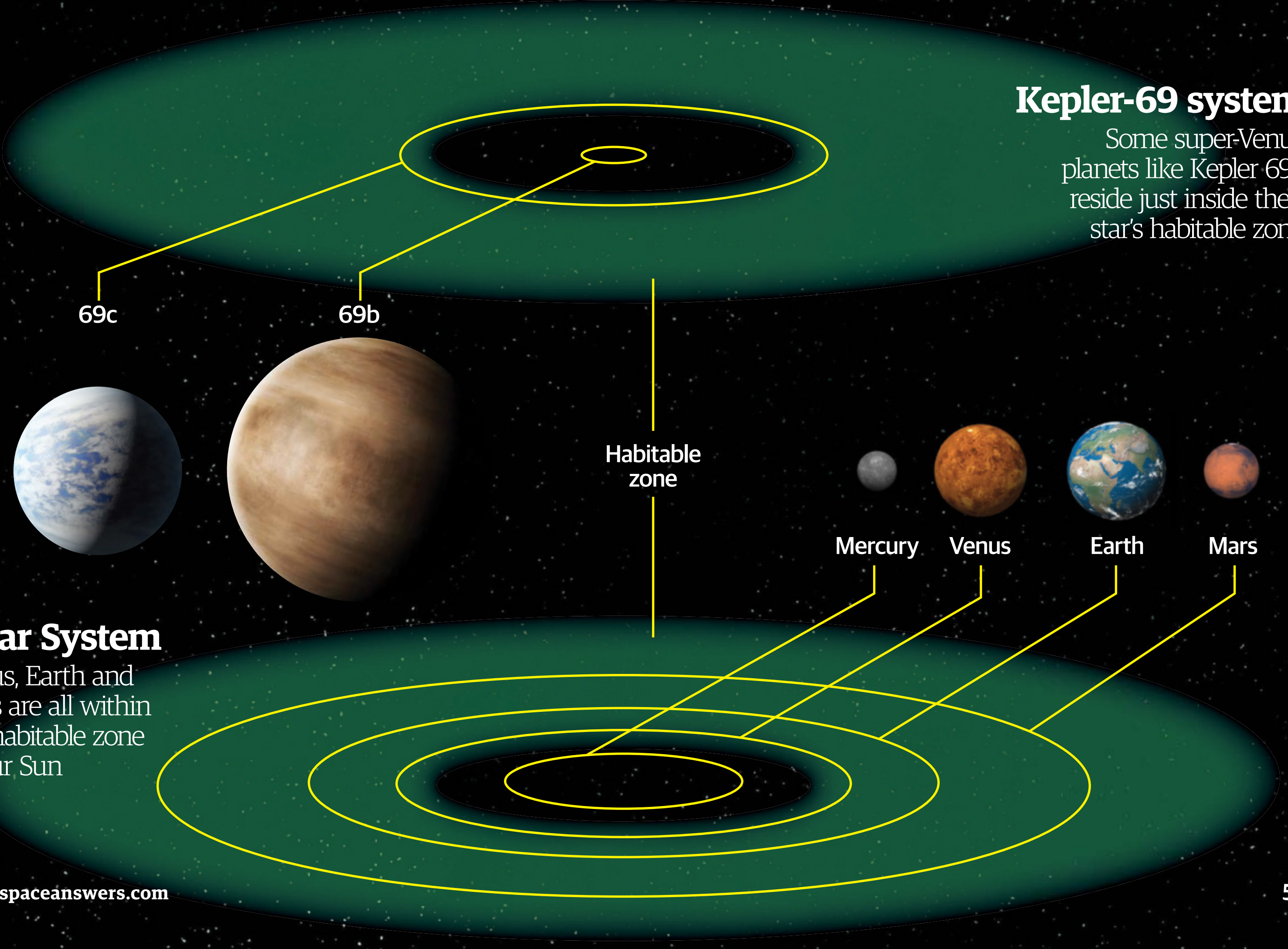


Gliese 1132b
Parent star: Gliese 1132
Distance (in light years): 39
Size (in Earths): 1.16
Estimate temperature: 230°C (440°F)
Discovered by: MEarth-South array



Gliese 832c
Parent star: Gliese 832
Distance (in light years): 16
Size (in Earths): Unknown (But mass is 5.4 Earths)
Estimate temperature: Unknown
Discovered by: Anglo-Australian Telescope, Magellan Telescope, European Southern Observatory

Inside the Goldilocks zone



Kepler-69 system

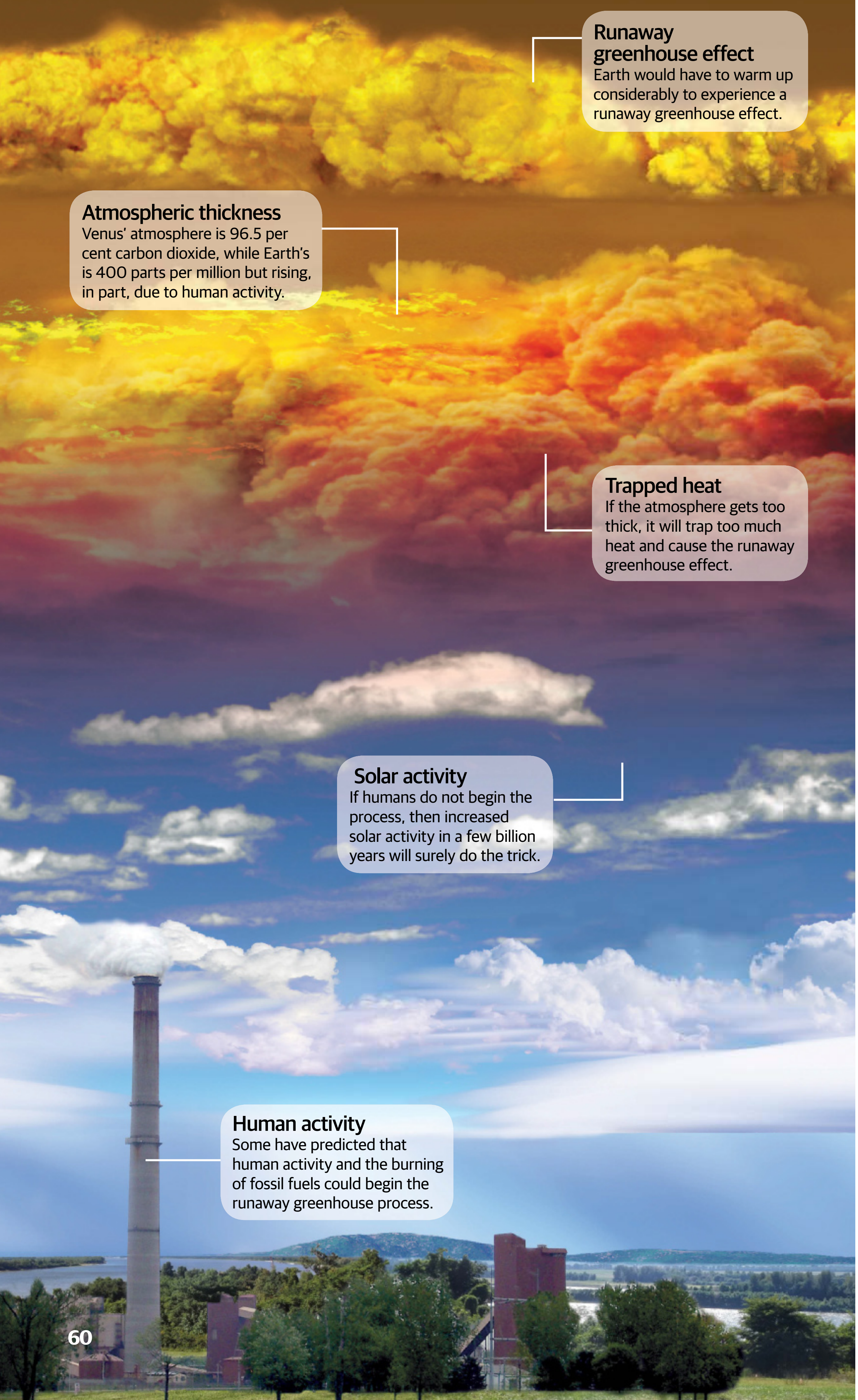
Some super-Venus planets like Kepler 69c reside just inside their star's habitable zone

Solar System

Venus, Earth and Mars are all within the habitable zone of our Sun

How Venus' past could become Earth's future

Could our planet turn equally barren and inhospitable?



Runaway greenhouse effect
Earth would have to warm up considerably to experience a runaway greenhouse effect.

Atmospheric thickness
Venus' atmosphere is 96.5 per cent carbon dioxide, while Earth's is 400 parts per million but rising, in part, due to human activity.

Trapped heat
If the atmosphere gets too thick, it will trap too much heat and cause the runaway greenhouse effect.

Solar activity
If humans do not begin the process, then increased solar activity in a few billion years will surely do the trick.

Human activity
Some have predicted that human activity and the burning of fossil fuels could begin the runaway greenhouse process.

be able to characterise the atmospheres of some of these worlds. They will do this by observing the light coming through their atmospheres, a process known as transmission spectroscopy, to ascertain both the presence of an atmosphere and its thickness, and perhaps even its composition.

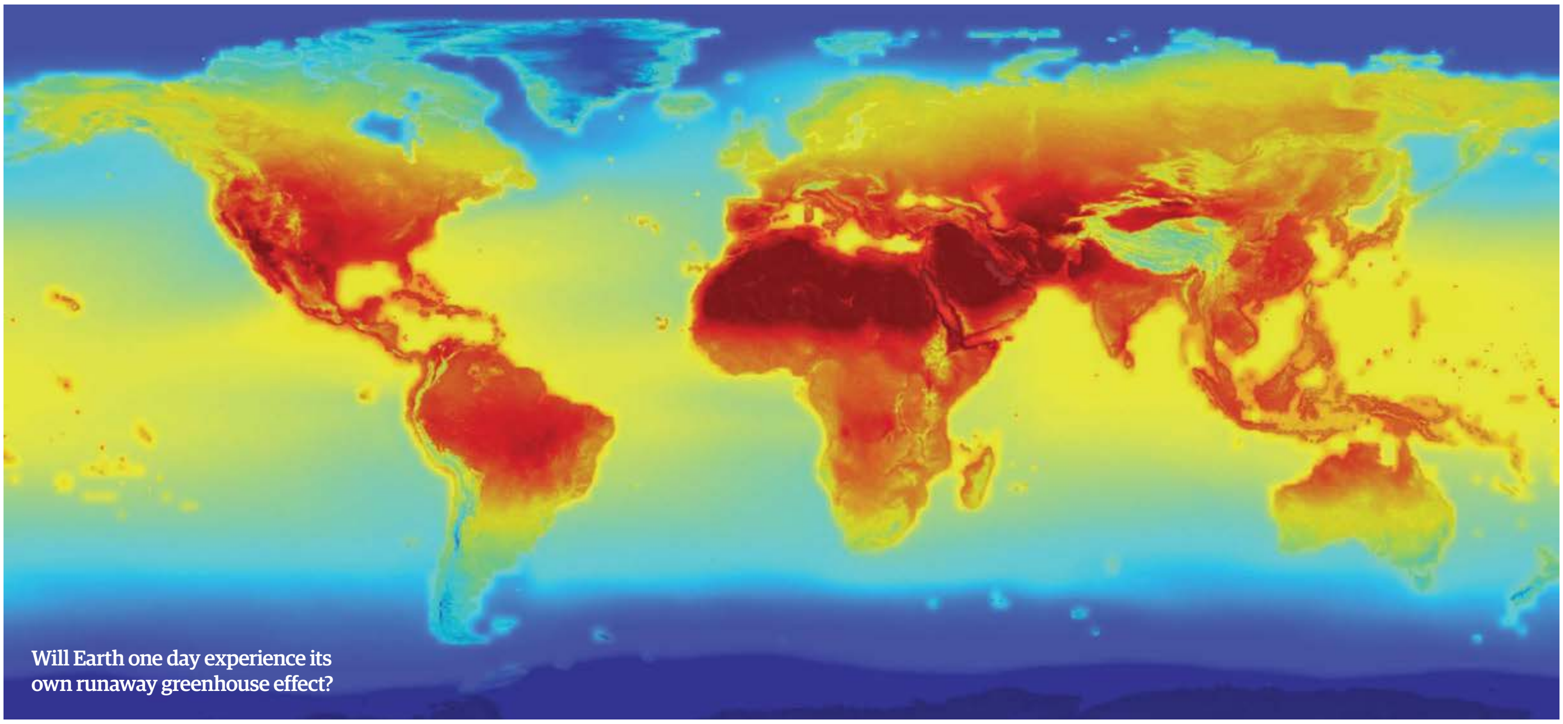
Inevitably, the question will fall on habitability. Could these worlds support life? The answer is complicated. For super-Venus exoplanets in tight orbits around their host star, it's extremely unlikely. Orbiting in a matter of days, they could be subjected to heat that would cause even rocks to sublimate (evaporate). Perhaps only if they were tidally locked - with one side of the planet always facing the star - could their exist a small region where life could exist between the scorching hot nearside and colder farside, but this is currently pure conjecture.

For those worlds found just inside the habitable zone, it's a bit more unclear. The energy from their host star will likely have evaporated any liquid water they once had long ago. Even if they receive a similar amount of sunlight to Earth, the expected thick atmosphere of these large worlds would raise the heat to an inhospitable level. But that atmosphere might also be a saving grace. We know that atmospheres cause weather systems - we see it on Saturn's moon Titan, Jupiter and, of course, Earth. Could a super-Venus also have a weather system, one that circulated heat around the planet?

"We know little about the exact parameters which determine the precise boundaries of a habitable zone, so in the case of Gliese 832c, which is right at the inner habitable zone boundary and even moves in and out of the inner edge with its slightly eccentric orbit, it is impossible to make categorical statements," says Beichman.

Perhaps importantly, in some extreme scenarios they may also be snapshots into what will become of Earth. As our atmosphere gets thicker, and more heat is trapped on our planet, we edge ever closer to undergoing our own runaway greenhouse effect. When this will happen is up for debate. Human activity has raised the amount of carbon dioxide to 400 million parts per million in our atmosphere. This is not much compared to the Venusian atmosphere, which is 96.5 per cent carbon dioxide, but there's little doubt our planet is warming up. Could it ever pass a point of no return? It almost certainly will in a few billion years, when our Sun's activity is expected to increase and subject our planet to more heat. Some super-Venus exoplanets, particularly those located at the inner edge of their habitable zones, appear to have gone through something similar. Our planet

> "We know little about the exact parameters which determine the precise boundaries of a habitable zone"
>
> **Dr Charles Beichman**



Will Earth one day experience its own runaway greenhouse effect?

may ultimately go the same way, with little chance of retaining liquid water. So, studying super-Venuses could provide more detail on what will happen.

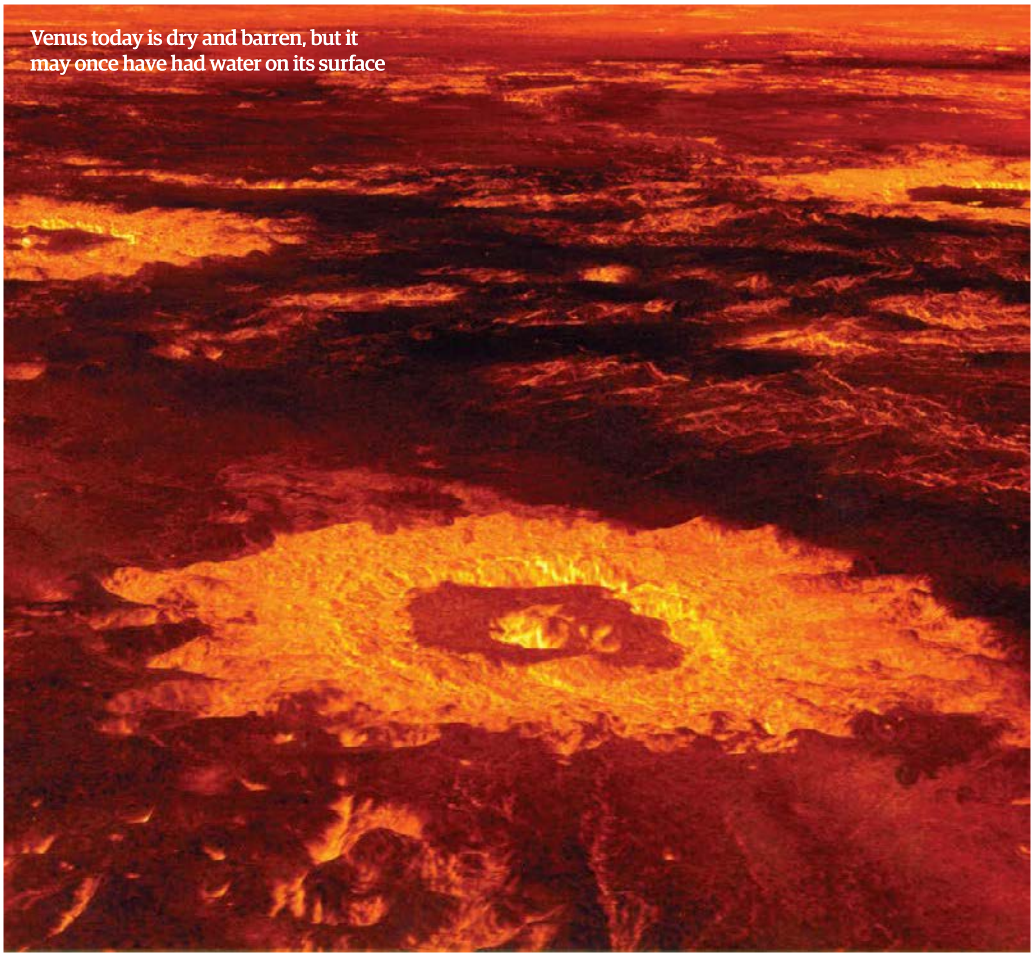
Scientists will be keen to work out the composition of these atmospheres, if possible, and see if there are any indications that they once had liquid water on their surface. Venus, for example, has large amounts of water vapour in its atmosphere - an indicator that it once had liquid water on the surface. And it's not like we will be short of planets to look at. While we know of only a handful of super-Venus exoplanets so far, there are hundreds of billions of planets in our galaxy - and several thousand are close enough for direct observations with current technologies.

"Data from the Kepler spacecraft suggests that up to 15 to 25 per cent of all small stars, such as Gliese 832, host planets in the Earth or Venus range and located in or around the habitable zone of the host star," says Beichman. "We know less about the planetary census for stars more like our Sun, but the preliminary statistics suggest fractions like 5 to 15 per cent for Earth-sized planets in the habitable zone."

Most of the recent focus in planet hunting has been on finding an Earth twin, and we are pretty close with worlds like Kepler 452b. But perhaps it is these super-Venus worlds that will prove to be of more interest in the near future. Those that orbit close to their stars, and are within 100 light years of Earth, will give us a fascinating opportunity to study atmospheres beyond our Solar System. This is an area of astronomy we are only just delving into - and scientists are keen to see what they will find.

"In the more distant future, we will launch space telescopes capable of imaging Earth-sized planets directly in the habitable zones of their host stars, and use spectroscopy to look for signatures of life, such as oxygen and ozone," says Beichman. Until then, we can use these super-Venus alien worlds as a testing ground, and in the process learn more about a type of terrestrial planet that is hugely exciting in its own right. ■

> "Data from Kepler suggests that 15 to 25 per cent of all small stars host planets in or around the habitable zone"



Venus today is dry and barren, but it may once have had water on its surface

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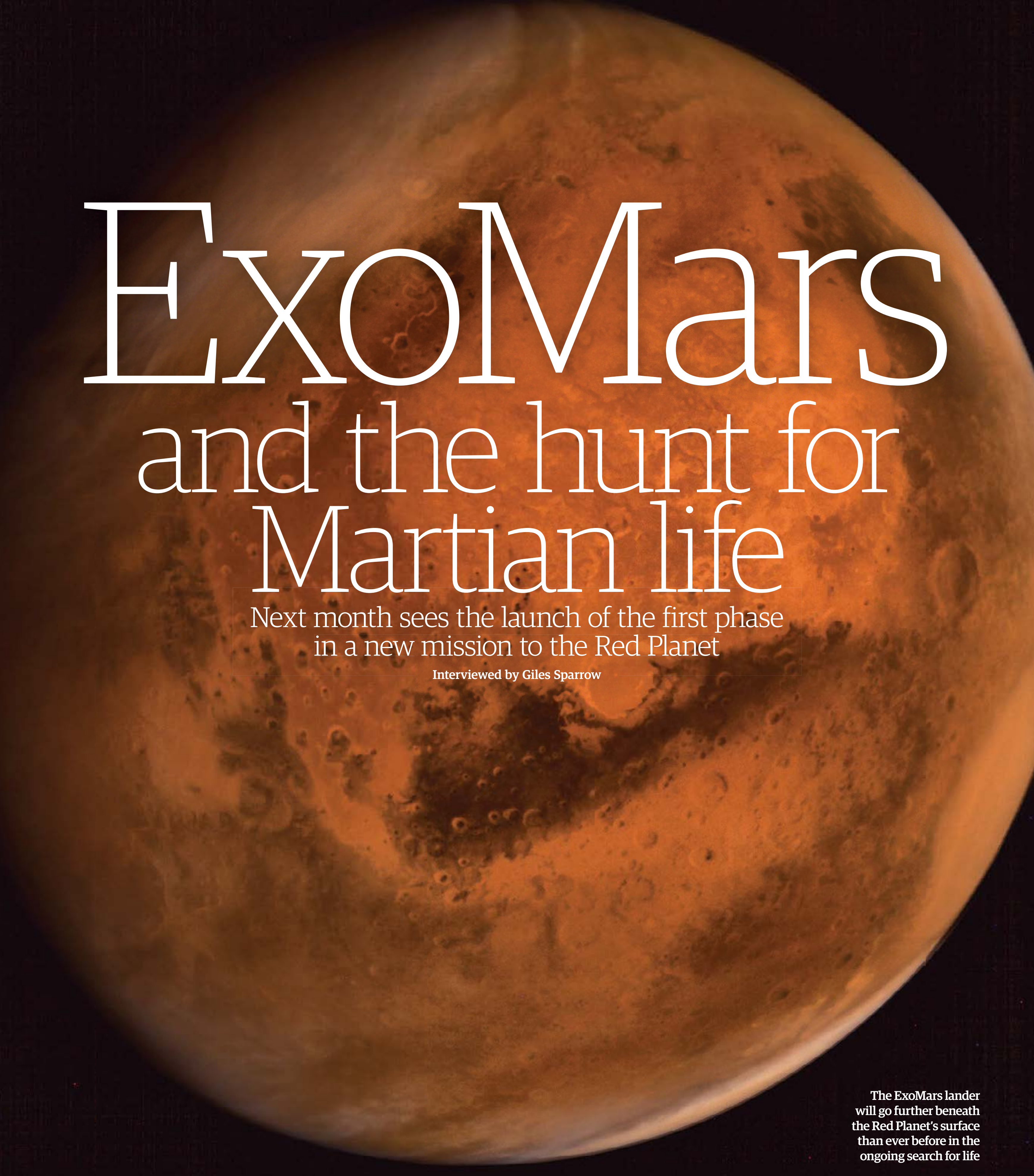


ExoMars and the hunt for Martian life

Next month sees the launch of the first phase in a new mission to the Red Planet

Interviewed by Giles Sparrow

The ExoMars lander will go further beneath the Red Planet's surface than ever before in the ongoing search for life

Firstly, can you give us a general overview of the ExoMars mission?

ExoMars involves two missions over two different launch windows in 2016 and 2018. The March 2016 launch includes the Trace Gas Orbiter, which is going to follow up on the discovery of methane on Mars that was made a few years ago. Methane in the Martian atmosphere is very interesting and worth investigating further. That mission is carrying a demonstration lander called Schiaparelli, which has a couple of scientific instruments onboard to look at the atmosphere during its descent, and study some surface features – though it doesn't have a camera to take images on the surface. It's going to land at the very end of the dust storm season on Mars, because if you can land then, you can land any time. And the third element of that mission, is that the orbiter also acts as a data relay to send back signals from the rover we're hoping to launch in 2018 to land in 2019.

The rover itself should be able to drill deep into the Martian surface for the very first time, to depths of up to two metres (6.6 feet). That's a big advance over previous missions – Curiosity can drill up to five centimetres (two inches) down and has made some fantastic discoveries of water-related minerals because of that, but we're going much deeper, looking for signs of past and even present life by searching for organic [carbon-based] chemicals. There's also a lander platform being provided by Russia, which has some more instruments onboard. The whole mission is a collaboration between the European Space Agency (ESA) and the Russian State Corporation Roscosmos.

How long have you been involved in the ExoMars project?

Well, we first proposed the camera for ExoMars back in 2003, around the time we were sending the British Beagle 2 lander (which unfortunately never sent back data from the surface). The Mars Express orbiter that took Beagle to Mars is still going strong, and we hope there's a chance it might still be operational by the time the Rover arrives.

We first wrote out a two-page proposal based on Beagle's stereoscopic camera system, but part of the remit was to involve European partners, which evolved naturally. We later merged with another team that had their own proposal, and as a result we've ended up with the current PanCam design – an extremely powerful instrument that's probably the most scientifically capable camera ever designed for Mars. I was lucky enough to end up leading the team, but we've had major contributions from German and Swiss colleagues in particular. We just delivered our first hardware for testing at Airbus at the end of last year, which is a great feeling. That was the structural and thermal model, we're building an accurate test model of the rover to validate that all of the parts fit together and we will subject it to vibration and shock tests to see how it will cope with the landing.

But the main thing is to validate the thermal models – Mars is a very harsh thermal environment, with temperatures that can reach zero to ten or more degrees Celsius (32 to 50 degrees Fahrenheit) on the dayside, but can plunge to -100 degrees Celsius (-148 degrees Fahrenheit) at night. With that happening every day, the heat variations are one of the biggest challenges to operating a rover on Mars.

The next step is the engineering model for making sure the electrical interfaces are right, testing the data system and checking that we can properly command the instruments. After that, we will build the flight model itself, which should be the one that goes to Mars, and an identical flight spare in case anything

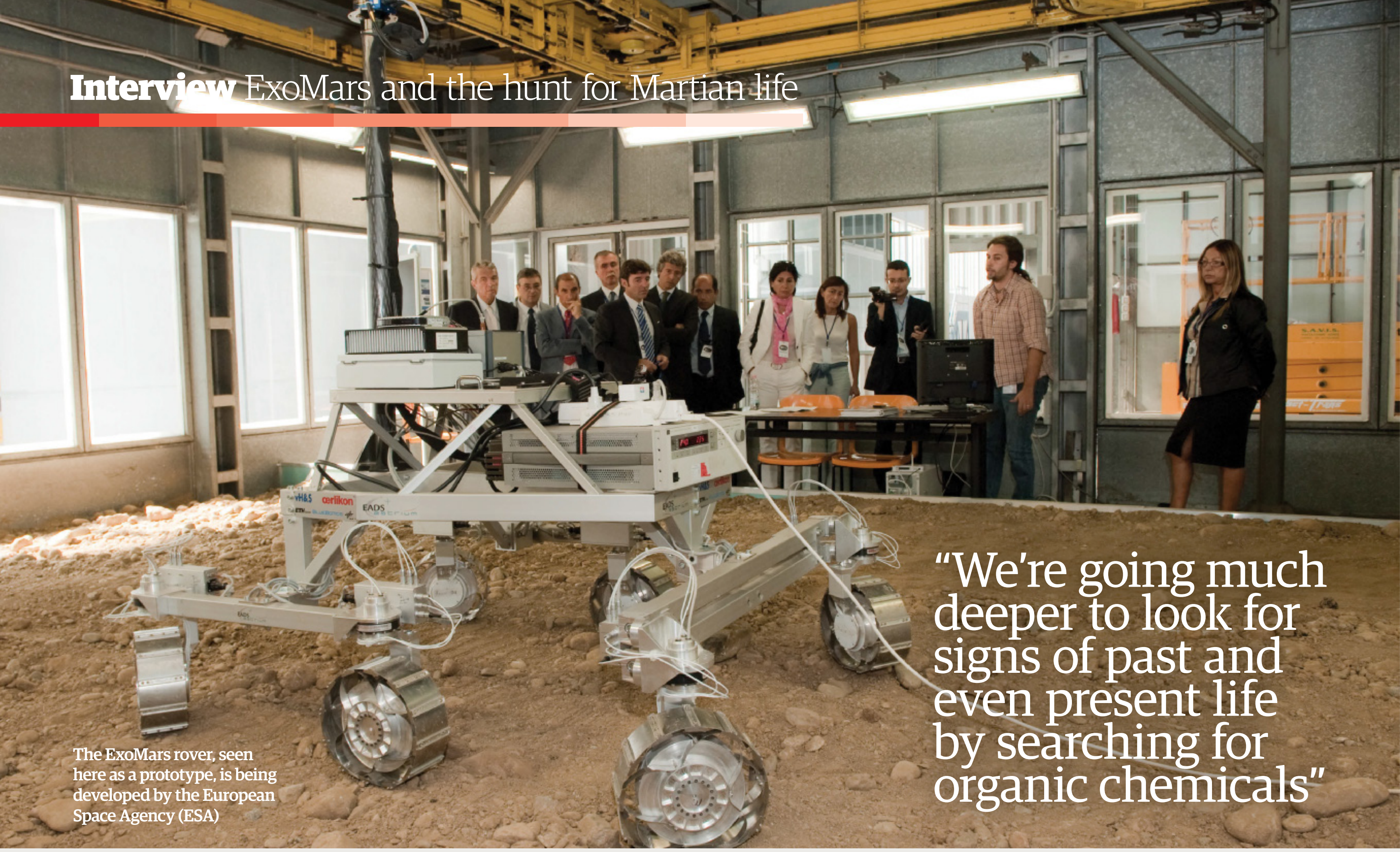
> "The rover should be able to drill deep into the Martian surface for the first time, to depths of two metres (6.6 feet)"

Component development, testing and construction for the ExoMars rover phase two is currently underway

INTERVIEW BIO

Professor Andrew Coates

Deputy director at the University College London's Mullard Space Science Laboratory, Andrew Coates has had a long career, working on instruments for many highly successful space probes, including the Giotto mission to Halley's Comet, NASA's Cassini mission to Saturn and the European Space Agency's Mars Express and Venus Express. He is principal investigator for the ExoMars 2018 rover's PanCam instrument.



The ExoMars rover, seen here as a prototype, is being developed by the European Space Agency (ESA)

> "We're going much deeper to look for signs of past and even present life by searching for organic chemicals"

happens to the flight model. Those deliveries will all come within the next year to 18 months.

So how will the rover get to Mars? Do you know where it will be landing yet?

ExoMars is in the 300-kilogram (661-pound) class of rovers – more like NASA's Spirit and Opportunity and much smaller than Curiosity. That means we don't need the complex 'skycrane' landing system that Curiosity used – we can reach the surface using a combination of heat shielding, parachutes and retrorockets. But when it comes to target selection, we still have to take a lot of engineering constraints into account, which narrow you down significantly in terms of where you can land using this kind of system. The parachutes and heat shielding need enough time to work properly, so you need to be below a certain altitude and depth of atmosphere.

Landing somewhere like the Moon is relatively straightforward – there's no atmosphere, so you can just use rockets – and re-entering the Earth's atmosphere is also fairly easy because the air is thick and you can rely on aerobraking and parachutes to do the work. But Mars has one per cent of Earth's atmospheric pressure, which is just enough to make things difficult. What's more, because the rover is powered by solar panels, we're limited to certain latitudes, between around five degrees south and 25 degrees north of the equator, where there's adequate sunlight throughout the Martian year. And, only once we've taken all of that into account can we look for sites of particular scientific interest, which tend to be where we see signs of ancient water having played some kind of role on the surface.

The ExoMars rover's PanCam is the most scientifically capable camera ever designed to study Mars

We initially had a list of eight potential sites for the 2018 landing, but at the end of last year we had our most recent landing site selection workshop, and we have now narrowed down our selection to three, of which the frontrunner is Oxia Planum. That's a particularly good one because Mars Express has found signs of phyllosilicates [hydrated clay minerals] on the surface, and there are also signs of a river delta. It seems to have been an outflow channel around 3.8 to 4.0 billion years ago, when Mars had a much thicker atmosphere and a magnetic field that would have made it much more hospitable for life.

If there's a delay to the 2020 launch window, then the trajectory of the rover's approach to Mars opens up the choice a bit more, and the alternative landing sites of Aram Dorsum and Mawrth Vallis are more likely to come into play.

Can you tell us how the rover's Panoramic Camera will work?

The special thing about PanCam is that we have a pair of good-resolution, wide-angle cameras, but each has a filter wheel on the front of it to study the surface at 11 specific colours and wavelengths. One of our PhD students helped in the wavelength selection, and they're specifically designed to look for water-bearing minerals, which should help us track down interesting targets for drilling. We can also do some atmospheric science with them, such as measuring the amount of water vapour in the atmosphere by looking at the sky and the way it affects certain wavelengths of sunlight.

The wide-angle cameras can give us very good stereo images for reconstructing the surface in 3D, as they're placed 50 centimetres (19.7 inches) apart – much wider than human eyes. They're supplemented by a high-resolution camera, which has a narrower field of view but a sharper image. Using that, we can add detailed texture to a 3D model of the surface near the rover, and it's that, along with the geological information, which will help us know where to drill.

To make sure that we get the most accurate colour in our images, our colleagues at the University of Aberystwyth are providing a calibration target so that we can take account of the different lighting conditions on Mars. They're actually using stained glass – this kind of material can survive unchanged in church windows for centuries, so by comparing its apparent colours on Earth and Mars, we can calibrate the camera.

Getting the shapes right is another challenge as the temperature changes inevitably introduce expansions and contractions in different parts of the rover, including the optics. The solution is to use fiducial markers – these are little spots on the rover whose positions we know and can accurately measure. They give us a scale of measurement, so if any distortions creep in we can calibrate them out.

How does PanCam work in relation to the rest of the rover's mission?

Well there are several other instruments in the rover's 'Pasteur' payload that will also help to put the geology of the rover's surroundings into context. The Infrared Spectrometer for Mars sits just beneath PanCam and allows us to study the infrared [heat] characteristics of rocks for even better mineral determination. There's also a subsurface sounding radar called WISDOM, which will help us to see how any interesting outcrops PanCam finds at the surface extend underground, helping us to work out where to drill. That radar can also search for water, as can a neutron detector.

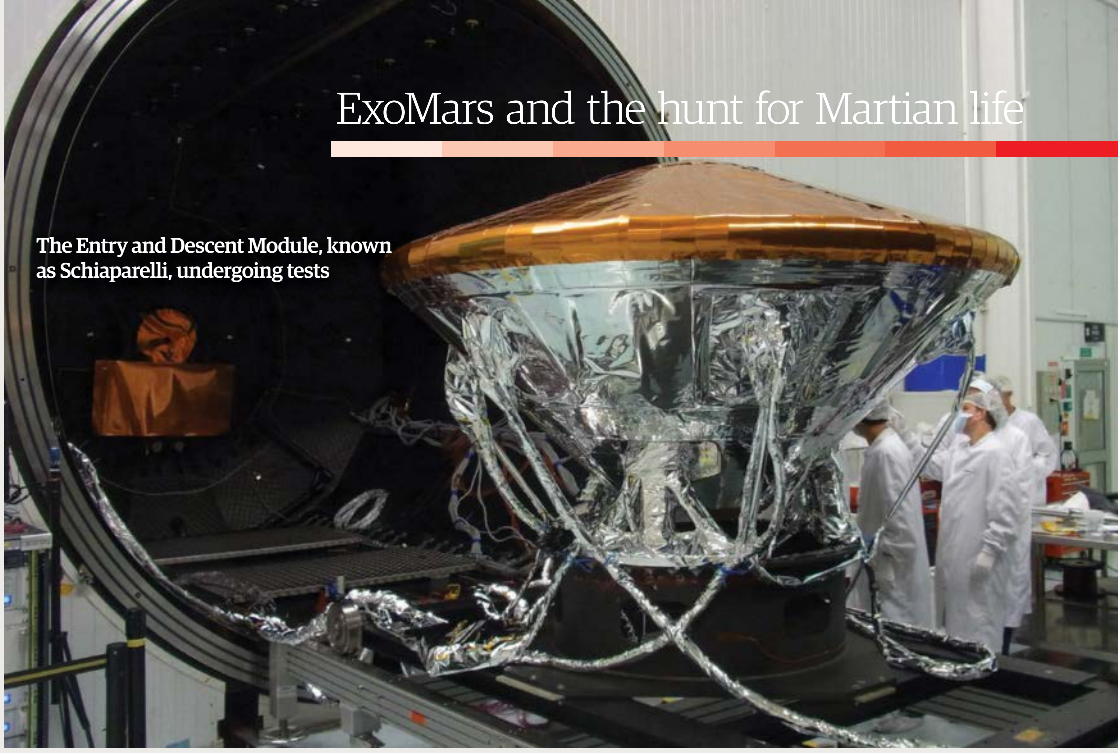
Obviously water is one of the key resources needed for the development of life, and that's why current missions have been focussed on water as a really important feature. But what we're doing is going for life head-on by looking for organics. Those instruments are all focused on the wider context of the samples we're collecting, but there's also a Close-up Imager for looking at samples – for instance the ones brought up by the drill – in even higher resolution, and another visible-infrared spectrometer called Ma-MISS inside the drill itself, which can look at the geological context right where you're drilling.

Once a sample has been collected, the analytical drawer pulls samples inside the rover itself to an analytical instrument suite. Here, a Raman spectrometer looks at fluorescence [associated with water-formed minerals], while an imaging spectrometer called MicrOmega will look at infrared properties. A third instrument called the Mars Organic Mass Analyser is the largest on the rover. It is a mass spectrometer capable of looking for carbonates, organic molecules and complexity including chirality – left or right-handed molecules.

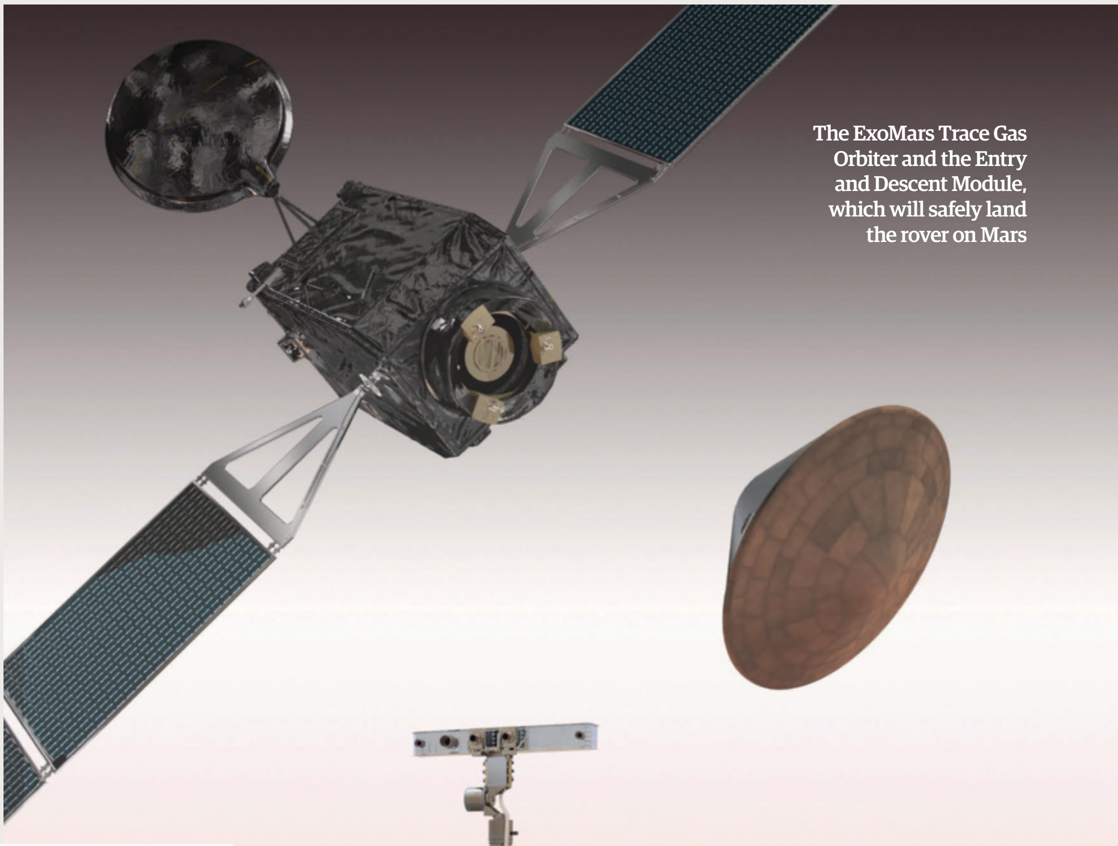
What are we looking for precisely?

Overall, we're looking for the type of chemistry which is relevant to life. By drilling up to two metres (6.6 feet) under the surface we're getting away from the damaging oxidising chemistry of the surface of Mars, the relatively high ultraviolet, and the high radiation caused by energetic particles from the Sun and the wider galaxy.

All of that means that life on the surface is most unlikely, and so drilling down is the best chance of finding it. It is a really big step forward to go underneath the surface and explore the third dimension on Mars for the first time. ■

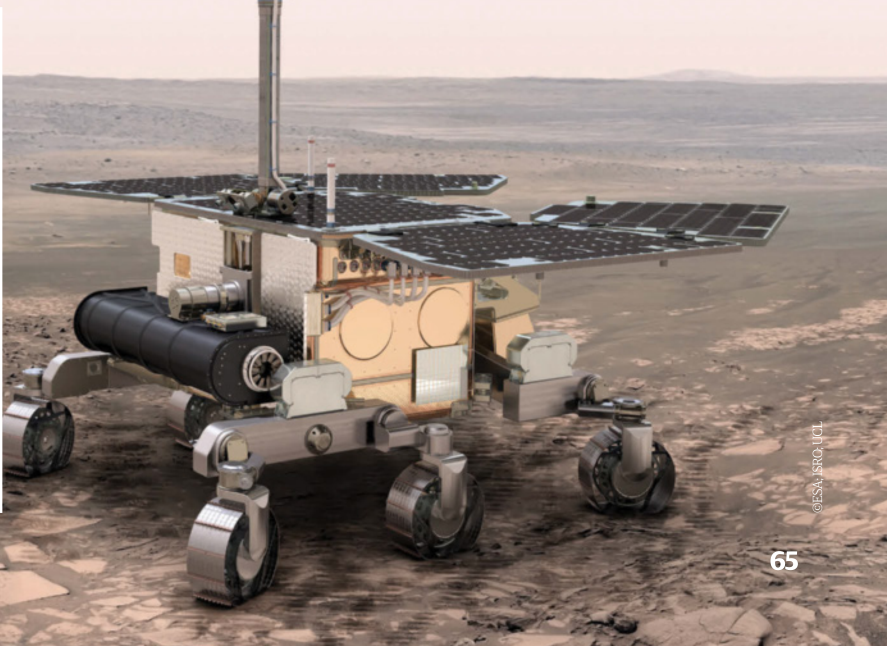


The Entry and Descent Module, known as Schiaparelli, undergoing tests



The ExoMars Trace Gas Orbiter and the Entry and Descent Module, which will safely land the rover on Mars

The entire ExoMars mission is a collaboration between the ESA and Roscosmos



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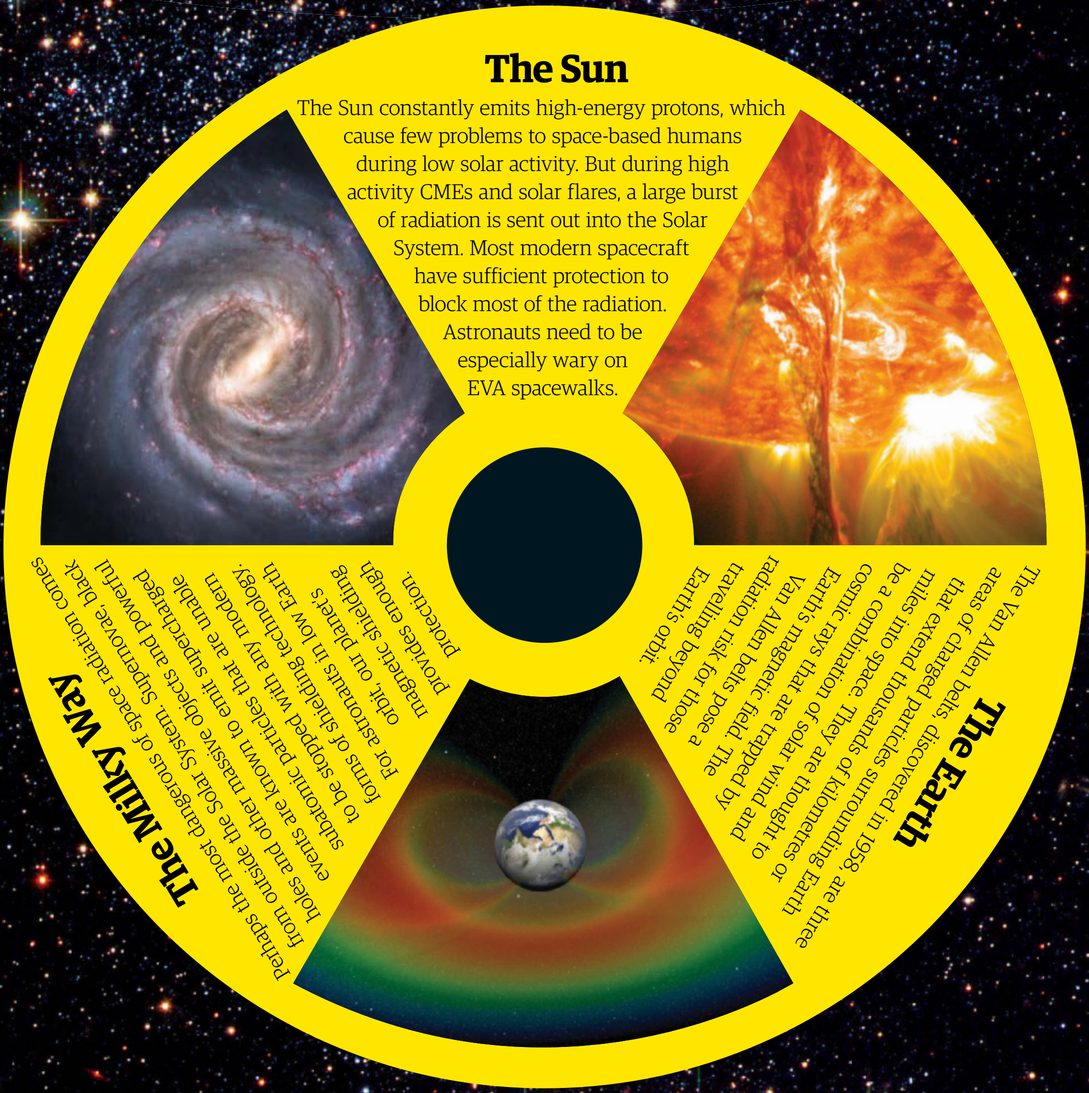
DEEP SPACE

Where does space radiation come from?

Marina House

Space radiation, which takes the form of subatomic particles, comes from a variety of sources in space. The particles that comprise the radiation can travel at incredibly high speeds, which makes them capable of tearing through DNA molecules, splitting them or damaging them so that they are unable to replicate. Damaged DNA can often lead to cancers if an astronaut was ever exposed to them. There are three main places where space radiation comes from - our Sun, supernovae and black holes in the Milky Way and - to some degree - our own planet. **GL**



The Sun

The Sun constantly emits high-energy protons, which cause few problems to space-based humans during low solar activity. But during high activity CMEs and solar flares, a large burst of radiation is sent out into the Solar System. Most modern spacecraft have sufficient protection to block most of the radiation. Astronauts need to be especially wary on EVA spacewalks.

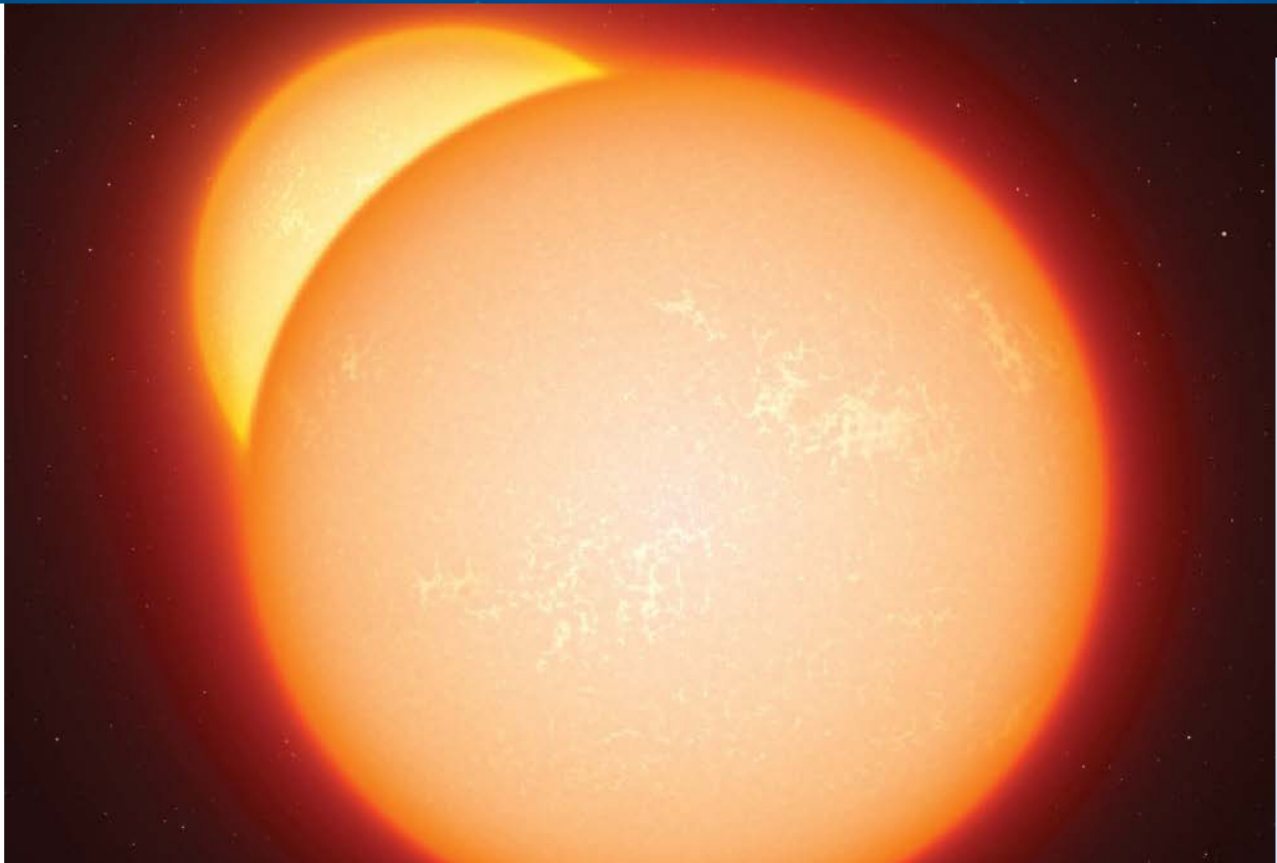
The Milky Way

Perhaps the most dangerous of space radiation comes from outside the Solar System. Supernovae, black holes and other massive objects and powerful events are known to emit supercharged subatomic particles that are unable to be stopped with any modern forms of shielding technology. For astronauts in low Earth orbit, our planet's magnetic shielding provides enough protection.

The Earth

The Van Allen belts, discovered in 1958, are three areas of charged particles surrounding Earth that extend thousands of kilometres or miles into space. They are thought to be a combination of solar wind and cosmic rays that are trapped by Earth's magnetic field. The Van Allen belts pose a radiation risk for those travelling beyond Earth's orbit.

Make contact: @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com



More than 50 per cent of stars are in binary systems

DEEP SPACE

Why are most stars in the universe in pairs?

Leanne Wilson

It's thought to be down to the way they form. Up to 50 per cent of all stars are in binary systems. However, some astronomers estimate that an even higher percentage of stars are born in pairs. Our theories of star formation suggest that most stars form in clusters rather than singularly. In the denser part of clusters, stars could have paired up, forming binary stars. Another way in which stars can end up in pairs is by the breaking up of discs around newly formed stars. Discs of gas and dust are a natural result of the star formation process due to the initial rotation of the interstellar cloud that collapses to make a star. A disc increases in mass as more material from the cloud falls onto it and can become unstable, or too heavy, to be maintained and fragments, breaking up into stars. If this happens quickly after the first star is formed, then the two stars may have similar masses. **GL**

Sundogs appear as coloured patches of light in the sky

ASTRONOMY

How are sundogs made?

Justine Hand

Sundogs - which usually appear as coloured patches of light in the sky to the left or right of the Sun - are caused by sunlight shining through ice crystals in the atmosphere. While sundogs can be seen with the Sun behind you, they are more conspicuous when safely looking towards the Sun when it's low in the sky. Sundogs are sometimes called by their scientific name, which is parhelion. They can usually be seen all year round, although they are most common in the winter when the Sun is low in the sky. **SA**

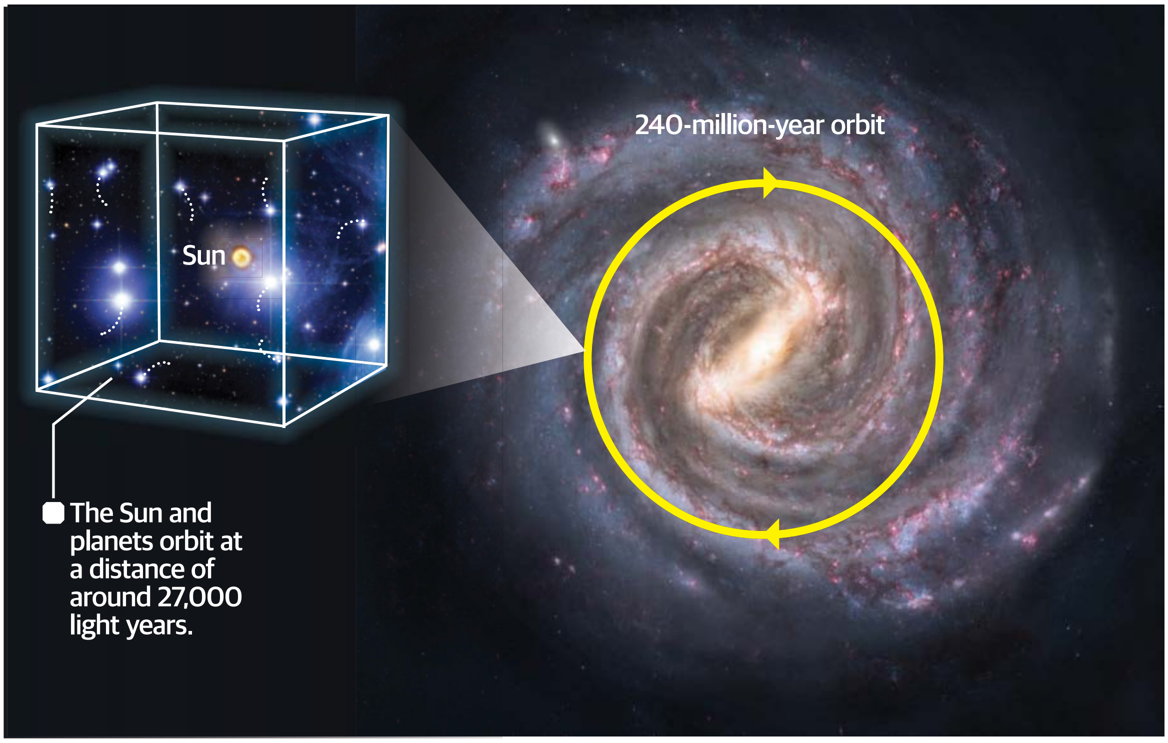
SOLAR SYSTEM

Does the Sun move in space?

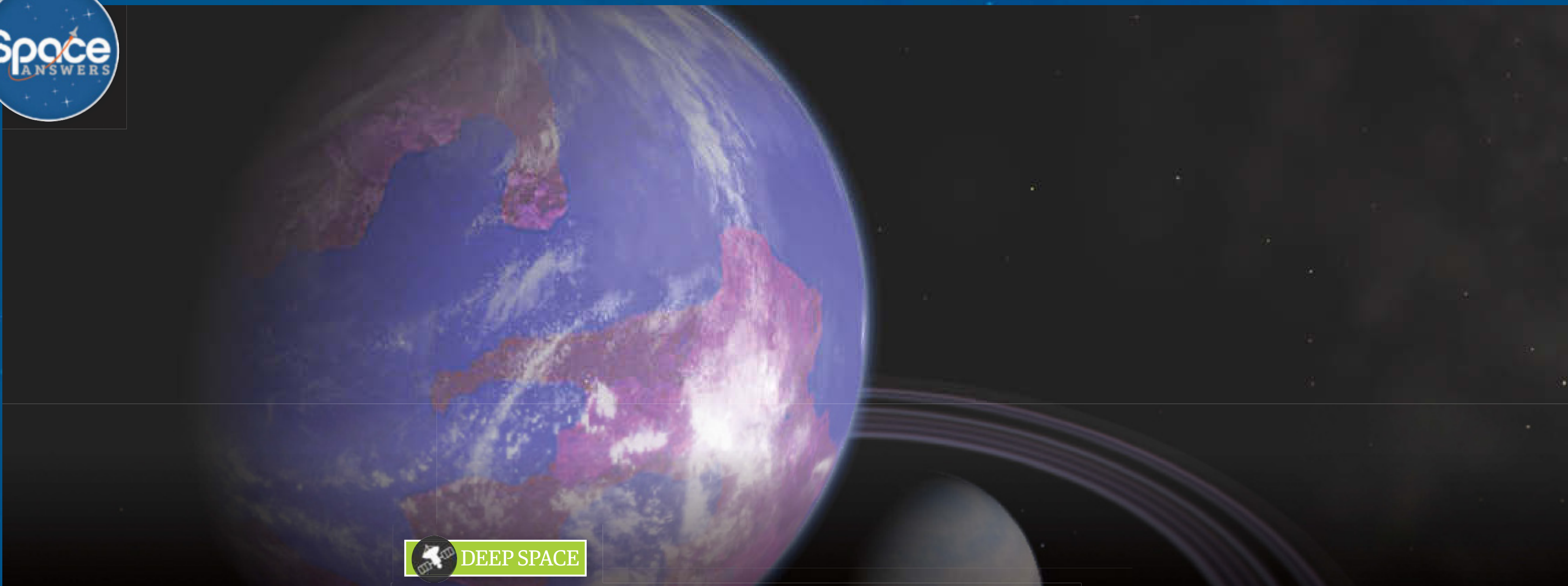
John Breen

Yes, it does. At an average speed of 720,000 kilometres (450,000 miles) per hour, the Sun - and therefore the planets in the Solar System - orbit the centre of the Milky Way galaxy at a distance of about 27,000 light years away. It actually takes about 240 million years to complete just one lap around our galaxy. As well as moving in an orbit, the Sun also rotates - however, not in the way that you might think.

Our Star's poles and equator move at different speeds in what is known as differential rotation. At the solar equator, it takes 25 days to complete one orbit and takes progressively longer to rotate the closer you get to the poles, where it can take anywhere up to 35 days. **JB**



The Sun and planets orbit at a distance of around 27,000 light years.



An artist's impression of an Earth-like moon in orbit around a Saturn-like exoplanet

DEEP SPACE

Do exoplanets have moons?

Matt Cox

Given that the majority of the planets in our Solar System have moons, it's very likely that they exist elsewhere in the universe around exoplanets, too. Of course, as moons are often much smaller than their host planets, it's difficult to prove that they exist outside the Solar System as we're observing from thousands of light years away.

But, despite the hurdle, astronomers use a technique known as gravitational microlensing, which takes advantage of chance alignments between stars, in an attempt to uncover any potential candidates. If one of these stars has a planet circling it, the alien world can act as a second lens to brighten or dim the light even more. Sadly, however - and as a team of exomoon hunters has recently discovered - microlensing effects can only usually be seen just the once, which makes declaring a new discovery extremely difficult. **GL**

SOLAR SYSTEM

There's a 99.998 per cent certainty that asteroid 2013 TV135 will miss Earth's orbit

Is asteroid 2013 TV135 going to hit us in 2032?

Keith Griffin

According to NASA, there's a 99.998 per cent certainty that this asteroid will miss Earth's orbit, putting the probability of an Earth impact at one in 63,000. Asteroid 2013 TV135 was discovered by astronomers at the Crimean Astrophysical Observatory in Ukraine, when it came within around 6.7 million kilometres (4.2 million miles) of Earth. The space rock is estimated to be 400 metres (1,300 feet) in size and its orbit carries it as far out as three quarters of the distance to Jupiter's orbit and as close to the Sun as Earth's orbit. With the Near-Earth Object Observations Programme - 'Spaceguard' - watching any rock that could be potentially hazardous, you can sleep safe in the knowledge that 2013 TV135 won't hit us in 2032. **ZB**

SOLAR SYSTEM

Could a supernova kill all life on Earth?

James Haughty

If it was close enough, then yes. Astronomers predict that if a supernova were to explode within 30 light years of us, a mass extinction would be possible. X-rays and the more energetic gamma rays brought about by a star's explosion would destroy Earth's ozone layer and ionise nitrogen and oxygen in the atmosphere, leading to the formation of large amounts of smog-like nitrous oxide in the atmosphere. Supernovae occur every 100 years in the Milky Way.

Since our galaxy is a large place though, and since the Sun is located near the outskirts of the Milky Way where few stars are massive enough to explode as a supernova, having one go off within 30 light years off us should, on average, happen only once every 100 million years. **SA**

If close enough, a supernova will kick-start a mass extinction

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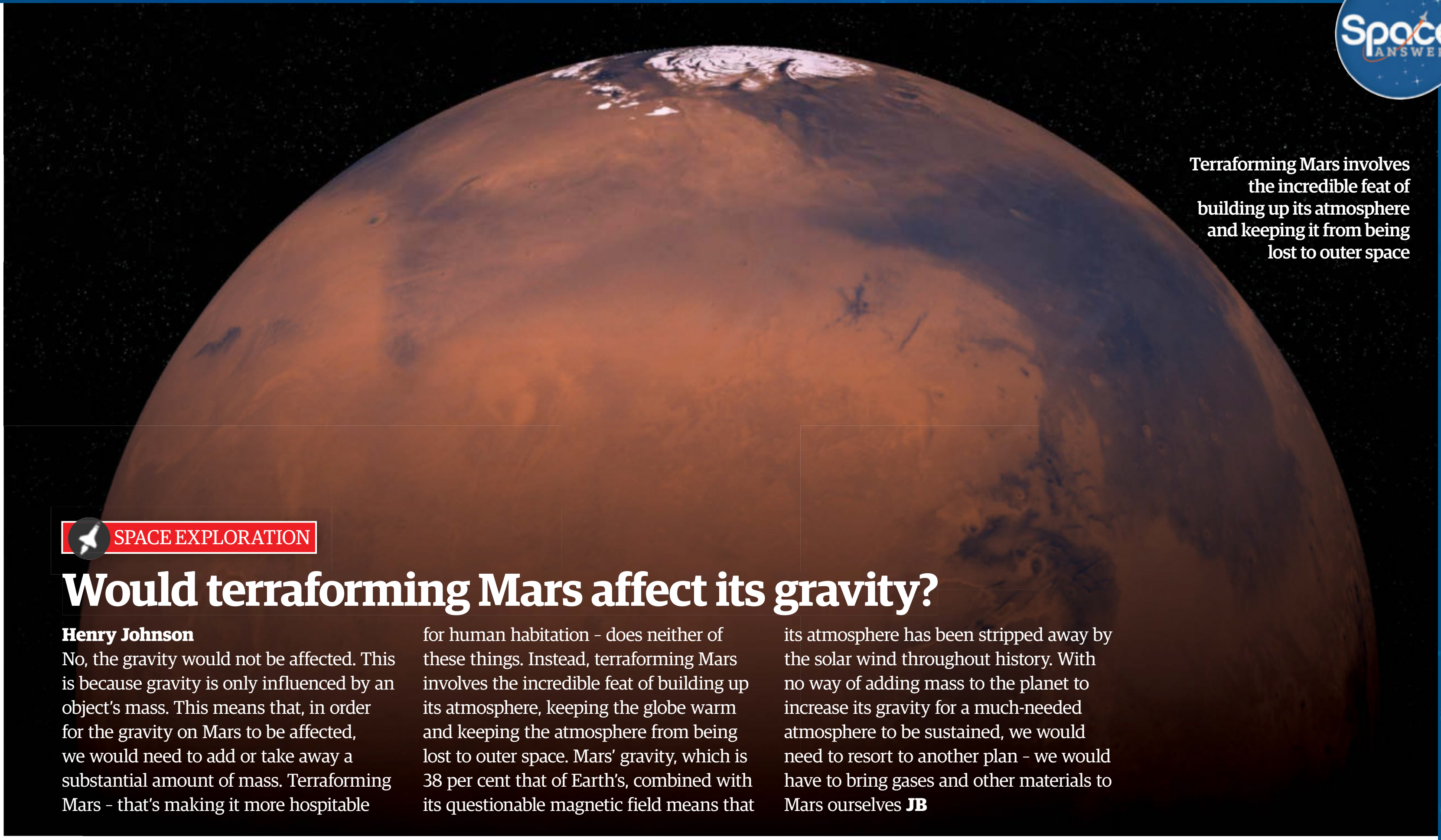


Terraforming Mars involves the incredible feat of building up its atmosphere and keeping it from being lost to outer space

SPACE EXPLORATION

Would terraforming Mars affect its gravity?

Henry Johnson

No, the gravity would not be affected. This is because gravity is only influenced by an object's mass. This means that, in order for the gravity on Mars to be affected, we would need to add or take away a substantial amount of mass. Terraforming Mars - that's making it more hospitable for human habitation - does neither of these things. Instead, terraforming Mars involves the incredible feat of building up its atmosphere, keeping the globe warm and keeping the atmosphere from being lost to outer space. Mars' gravity, which is 38 per cent that of Earth's, combined with its questionable magnetic field means that its atmosphere has been stripped away by the solar wind throughout history. With no way of adding mass to the planet to increase its gravity for a much-needed atmosphere to be sustained, we would need to resort to another plan - we would have to bring gases and other materials to Mars ourselves **JB**

DEEP SPACE

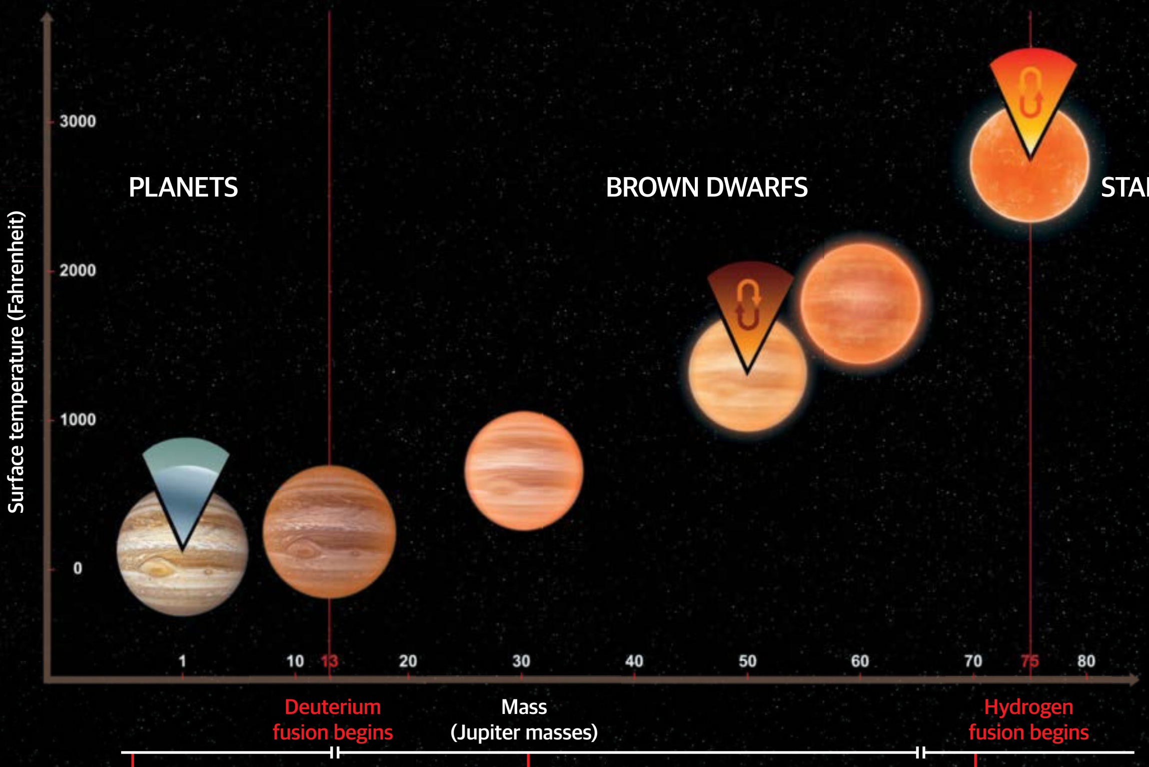
How are planets without stars made?

Samuel Richards

Worlds that don't orbit a star and wander the galaxy alone, known as rogue planets, may have formed in a planetary system similar to how the planets in our Solar System - and any other star-orbiting world for that matter - did, before being cast out by another planet in their system and forced to wander the universe alone.

Alternatively, and according to some scientific theories, a rogue planet may have never been bound to a parent star in the first place. Worlds that have a mass that's typical of a planet and that have enough gravity to take on a round appearance - but not enough gravity to sustain fusion in their core like a star can - might have formed in a similar way to a star.

Astronomers call these rogue objects sub-brown dwarfs, which formed through the collapse of a gigantic gas cloud. **GL**



No mixing

There's not too much mixing in the gaseous atmosphere of planets like Jupiter. The king of the Solar System prefers to keep some of its contents separate, with molecular hydrogen and helium gases separate from its metallic hydrogen centre.

No nuclear fusion

With no nuclear reactions occurring in a brown dwarf, its lithium isn't destroyed – objects that have an abundance of this soft metal are often suspected to be brown dwarfs. These failed stars are thought to be fully convective, meaning that they like to mix up their contents.

The industrious star

Stars have powerhouses at their centre and there is a great deal of turbulence with plenty of mixing. The heat and light making nuclear reactions in a star's core convert hydrogen into helium. Due to the exotic conditions, lithium isn't able to survive in stars such as red dwarfs.

© NASA; ESO

SPACE EXPLORATION

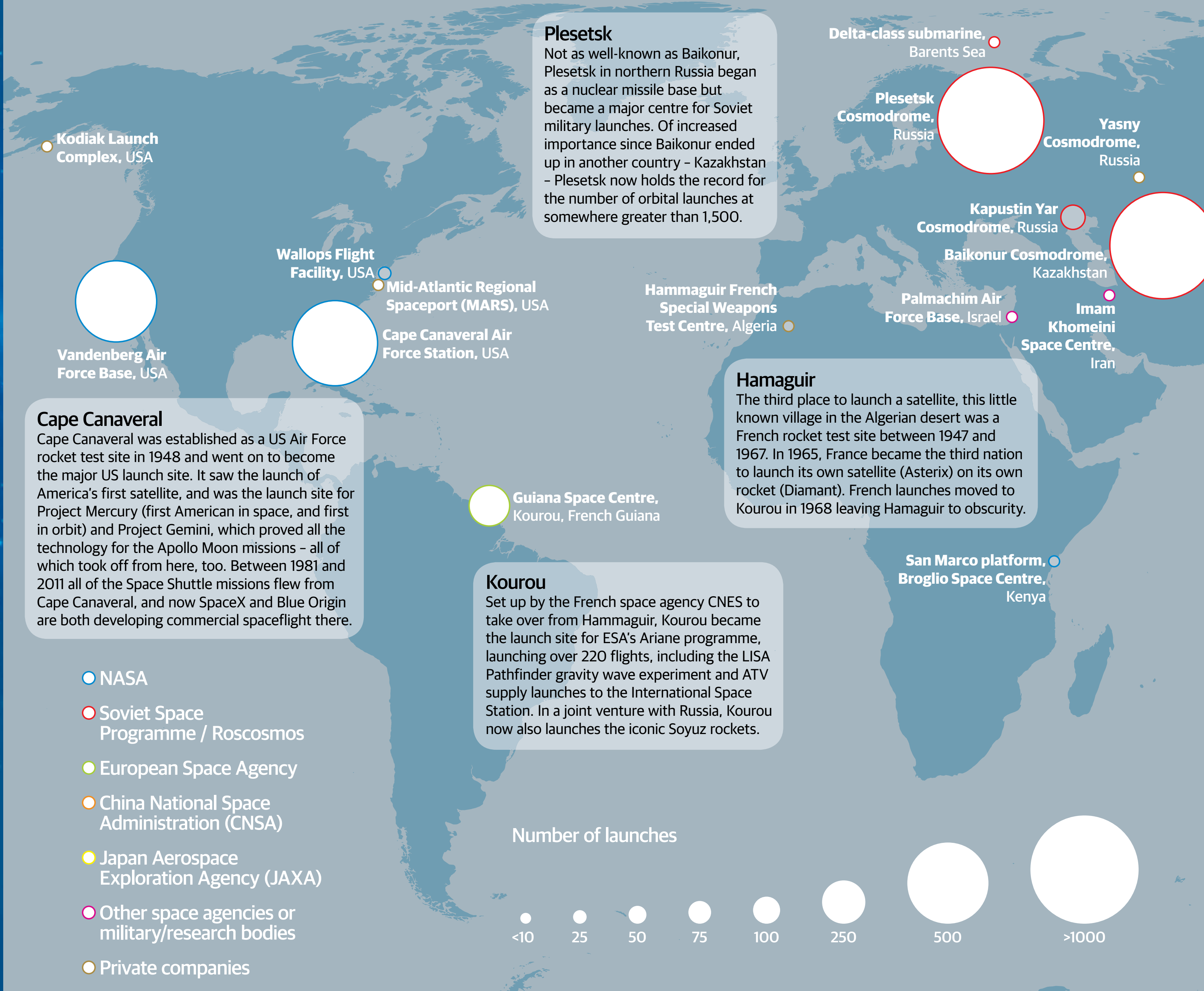
Where have we launched the most rockets from?

Sharon Hart

Several places! If you ask most people to name a launch site it will be Cape Canaveral. The main US launch site has dominated space history both because of the Apollo Moon missions, and because of America's open approach to its launches. Another, smaller group will name Canaveral's opposite number in the former Soviet Union, Baikonur; the launch site where Yuri Gagarin took off for humanity's first spaceflight. Europe's launch site at Kourou in French Guiana would probably come in a respectable third, but despite these three dominating the public consciousness, there are 25 sites around the world where rockets have been launched into orbit.

China, India and Japan all have active orbital launch sites, and Brazil has its own launch site and developing launch vehicle programme. South Korea and North Korea have both launched from the Korean peninsula, and Iran and Israel have launched from their own territory, with Israel uniquely launching westwards to avoid dropping stages on the countries eastwards.

A further, smaller group of respondents may mention the historic Woomera launch site in Australia. It was here, at the dawn of the space age, that Britain became a leader in re-entry studies and where it began the first joint European launcher programme. In 1971, the Black Arrow rocket made the UK the sixth country to launch its own rocket. **RH**


Delta-class submarine, Barents Sea
Plesetsk Cosmodrome, Russia
Yasny Cosmodrome, Russia
Kodiak Launch Complex, USA
Kapustin Yar Cosmodrome, Russia
Baikonur Cosmodrome, Kazakhstan
Wallops Flight Facility, USA
Mid-Atlantic Regional Spaceport (MARS), USA
Hammaguir French Special Weapons Test Centre, Algeria
Palmachim Air Force Base, Israel
Imam Khomeini Space Centre, Iran
Cape Canaveral Air Force Station, USA
Vandenberg Air Force Base, USA
Guiana Space Centre, Kourou, French Guiana
San Marco platform, Broglio Space Centre, Kenya
○ NASA
○ Soviet Space Programme / Roscosmos
○ European Space Agency
○ China National Space Administration (CNSA)
○ Japan Aerospace Exploration Agency (JAXA)
○ Other space agencies or military/research bodies
○ Private companies
Number of launches
<10
25
50
75
100
250
500
>1000

Plesetsk

Not as well-known as Baikonur, Plesetsk in northern Russia began as a nuclear missile base but became a major centre for Soviet military launches. Of increased importance since Baikonur ended up in another country – Kazakhstan – Plesetsk now holds the record for the number of orbital launches at somewhere greater than 1,500.

Cape Canaveral

Cape Canaveral was established as a US Air Force rocket test site in 1948 and went on to become the major US launch site. It saw the launch of America's first satellite, and was the launch site for Project Mercury (first American in space, and first in orbit) and Project Gemini, which proved all the technology for the Apollo Moon missions – all of which took off from here, too. Between 1981 and 2011 all of the Space Shuttle missions flew from Cape Canaveral, and now SpaceX and Blue Origin are both developing commercial spaceflight there.

Hamaguir

The third place to launch a satellite, this little known village in the Algerian desert was a French rocket test site between 1947 and 1967. In 1965, France became the third nation to launch its own satellite (Asterix) on its own rocket (Diamant). French launches moved to Kourou in 1968 leaving Hamaguir to obscurity.

Kourou

Set up by the French space agency CNES to take over from Hammaguir, Kourou became the launch site for ESA's Ariane programme, launching over 220 flights, including the LISA Pathfinder gravity wave experiment and ATV supply launches to the International Space Station. In a joint venture with Russia, Kourou now also launches the iconic Soyuz rockets.

Baikonur

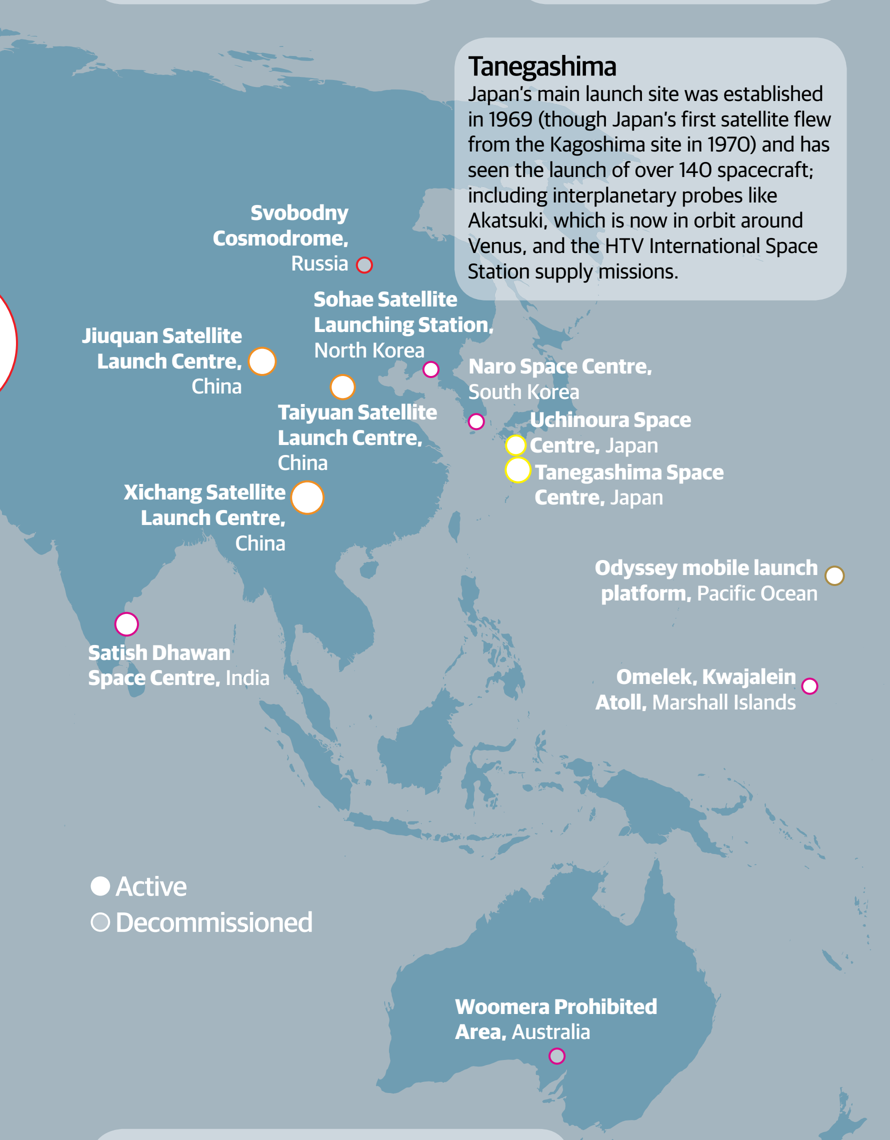
The Soviet Union's primary launch site was the starting point for many space firsts; Sputnik, the first satellite, Yuri Gagarin and Valentina Tereshkova's flights (Vostok 1 and Vostok 6), first multiple crew (Voskhod 1), first space station (Salyut 1), first escape velocity (Luna 1) and many more. It continues to be Russia's human spaceflight centre, despite now being in Kazakhstan.

Jiuquan

China's main launch centre is located 1,600km (994 miles) from Beijing in the Gobi desert; it launched China's first satellite in 1970 and with Shenzou 5 in 2003 became only the third human spaceport. The Shenzou human spaceflight programme continues to be based here and saw the launch of China's first space station module Tiangong 1 in 2011.

Tanegashima

Japan's main launch site was established in 1969 (though Japan's first satellite flew from the Kagoshima site in 1970) and has seen the launch of over 140 spacecraft; including interplanetary probes like Akatsuki, which is now in orbit around Venus, and the HTV International Space Station supply missions.


Svobodny Cosmodrome, Russia
Sohae Satellite Launching Station, North Korea
Jiuquan Satellite Launch Centre, China
Taiyuan Satellite Launch Centre, China
Naro Space Centre, South Korea
Uchinoura Space Centre, Japan
Tanegashima Space Centre, Japan
Xichang Satellite Launch Centre, China
Odyssey mobile launch platform, Pacific Ocean
Satish Dhawan Space Centre, India
Omelek, Kwajalein Atoll, Marshall Islands
● Active
○ Decommissioned
Woomera Prohibited Area, Australia

Woomera

Of special interest to the UK, Woomera in South Australia was established as a rocket test range in 1946. It was the site of all major UK launches – 22 suborbital Black Knight rockets in support of the Blue Streak programme. Blue Streak became the basis for the first joint European launcher Europa, which also flew here before the programme moved to Kourou in 1971. But it was here in October 1971 that the British Black Arrow rocket launched the Prospero satellite, making the UK the sixth country to develop its own complete orbital system.

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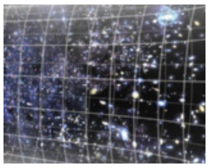
Next Issue

10 YEARS AROUND MARS

Celebrating a decade of the Mars Reconnaisance Orbiter



IS THE UNIVERSE A HOLOGRAM?

Meet the scientists figuring out if the cosmos really is as it seems

WHO OWNS THE MOON?

The trials and tribulations of colonising the Solar System

FALLING INTO A BLACK HOLE

Plus 10 other out-of-this-world space experiences

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YOUR SPACE QUESTIONS
SPACE PLANT SOLAR POWER
TRAVELLING WITH A ROVER
HOW TO TRACK JUPITER'S MOONS
TOTAL SOLAR ECLIPSE 2016

Stargazing with Mark Thompson

The astronomer and presenter of *Stargazing Live* talks about his time on the show and how you can get started in astronomy

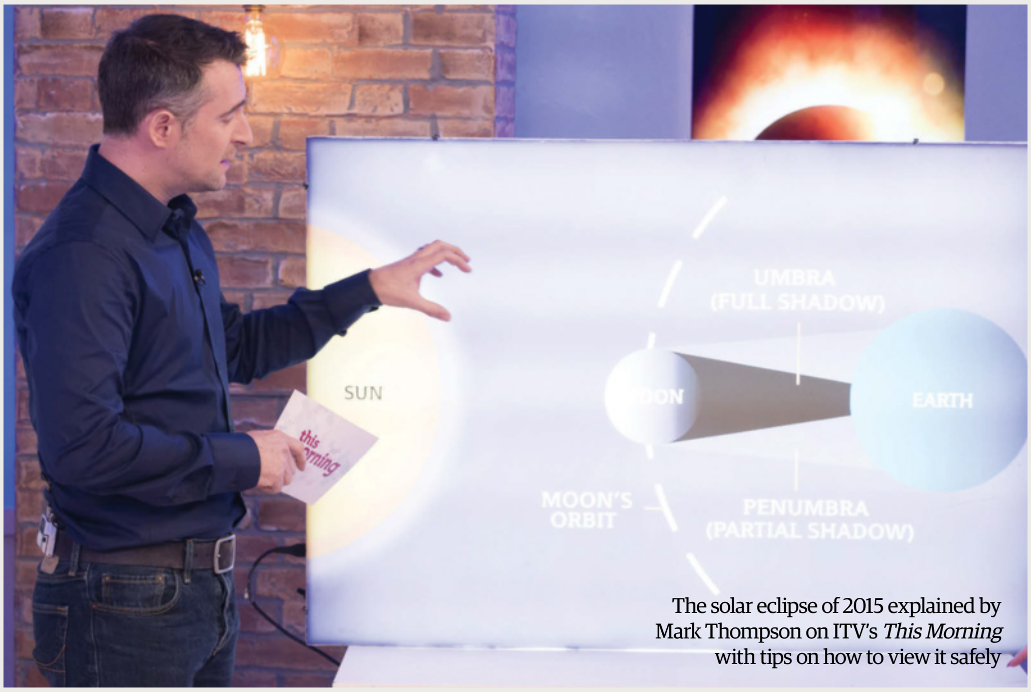
Interviewed by Gemma Lavender

When did you become interested in astronomy?
I was a mere ten years old when I had my first astronomical experience, when my dad took me along to my local astronomical society in Norwich. I don't think I was all that bothered about going at the time; I was just dragged along as an excuse to get me going places. I saw Saturn through the telescope at Norwich Astronomical Society and that hooked me. I can still vividly remember seeing Saturn and can see the image in my mind, and it was enough to inspire me to learn more about the universe. For my dad, that was enough. Once he had seen a few things, that was it - he was happy with that - but for me it kicked off the interest.

How did you get involved in *Stargazing Live*?
I had done a bit of work for the BBC before *Stargazing Live*'s first series, so my first experience of national television was presenting some films for *The One Show*, and I worked for five years with *The One Show* on and off doing astronomy features. I love working on shows like that because it's not a science programme, so you get people tuning in to watch who are not necessarily interested in science and it is an opportunity to inspire and drag other people into the subject and get them interested. A producer for *Stargazing Live* saw me on *The One Show* and I went down and met with them just before the first series kicked off.

What is your most memorable moment during your time on *Stargazing Live*?
It would have to be the very first series when I missed a meteor! Most of my work was outside in the dark and we used a special low-light camera. I'd just literally finished presenting to camera and I said - and bear in mind this was live on national television - that it was cloudy and you couldn't see anything. But just as luck would have it, behind my head was a patch of clear sky and a meteor went over my shoulder, so four million people saw this meteor just as I said it was cloudy and that I couldn't see anything! Everyone in the world saw it but me, the camera crew saw it and were waving at me but, of course, I couldn't see them because it was dark, and Dara (O'Briain) and Brian (Cox) saw it because they watched it on the monitor, but I was completely oblivious. I've not lived it down since!

> "I can still vividly remember seeing Saturn through a telescope and it was enough to inspire me to learn more"



The solar eclipse of 2015 explained by Mark Thompson on ITV's *This Morning* with tips on how to view it safely

What was it like to work with Brian Cox and Dara O'Briain?
It was brilliant, it was a really good mix because Brian has a great knowledge of how the universe works, and Dara is a very capable scientist in his own right, he's got a theoretical physics degree, and it all worked very well. Of course, Dara was used to doing live television, whereas the rest of the team did not have any real experience of presenting a live show, but I think Dara got a lot of negativity from the viewers because often he'd have to stop Brian talking if Brian was talking quite a lot. In live television you have to keep things moving on quite strictly, and Dara's very good at that. But I think to the viewer it looked like he just wanted to shut Brian up and move onto the next thing, but that was an important skill that Dara brought to the show that enabled it to work. It was good fun working with them.

Amateur astronomy has become more popular than ever thanks to *Stargazing Live*, how does it feel to have been a part of that?
Wonderful, because I've come from an amateur astronomy background and I've seen the impact that it's had on amateur astronomy around the country. Societies up and down the country have had a significant increase in the amount of people that are interested in going along to their public events and their observing events. And, to be a part of the team that made astronomy popular in the UK is fantastic, and it's great to see that it is carrying on - that it wasn't just a one-hit wonder!

What advice would you give to someone wanting to get started in astronomy?

INTERVIEWBIO

Mark Thompson
Mark is an astronomer, television presenter and writer best known for being part of the presenting team on the BBC show *Stargazing Live*. As well as being an enthusiastic astronomer, Mark is a qualified pilot and has written a selection of books on how to get started in astronomy. His most recent book is *Philip's Stargazing with Mark Thompson*.

One of the first things to do is not to rush out and buy a telescope. People think you need a telescope to enjoy the night sky, and yes it helps, but there are a lot of telescopes out there and you can end up wasting your hard-earned cash on something that's not right for you. So I think the best piece of advice is to go along to your local astronomy society first, because there are a lot of people at societies all over the country who have got a lot of experience and they can help you make the right choice as to what kind of telescope to get.

You might find that actually, astronomy is not for you and if you've spent £4,500 [approximately $6,500] on a telescope you might be a bit peeved by it! So I think by going to an astronomical society you can see what kind of telescopes are out there, talk to people about what kind of things in astronomy inspire you, and then make sure that you buy the right telescope for your interests, rather than waste money on something that you might not actually need.

You've released several books about astronomy, are there any more in the works?
Yes, absolutely there are. I've got some more books coming out with Philips, and we're looking at reproducing some of the books that have been out on the market with Philips for quite a few years now, but I'm not sure we have got any release dates yet.

When will you be on *Stargazing Live* next?
I don't know is the honest answer. The last couple of years I haven't been able to make it work. I'm a freelance person in the world of television, as I do also work for *ITV* and *Channel 5*, so the last couple of years I have been doing other things. ●

Mark Thompson on ITV's *This Morning* showing viewers how to create a meteor

© Rex Features

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

What's in the sky?

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22 FEB 🔭
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27 FEB 🔭
Comet 81P/Wild reaches its brightest in Taurus

29 FEB 👁
Conjunction between the Moon and Mars in Libra

Jargon buster

Conjunction
An alignment of celestial objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

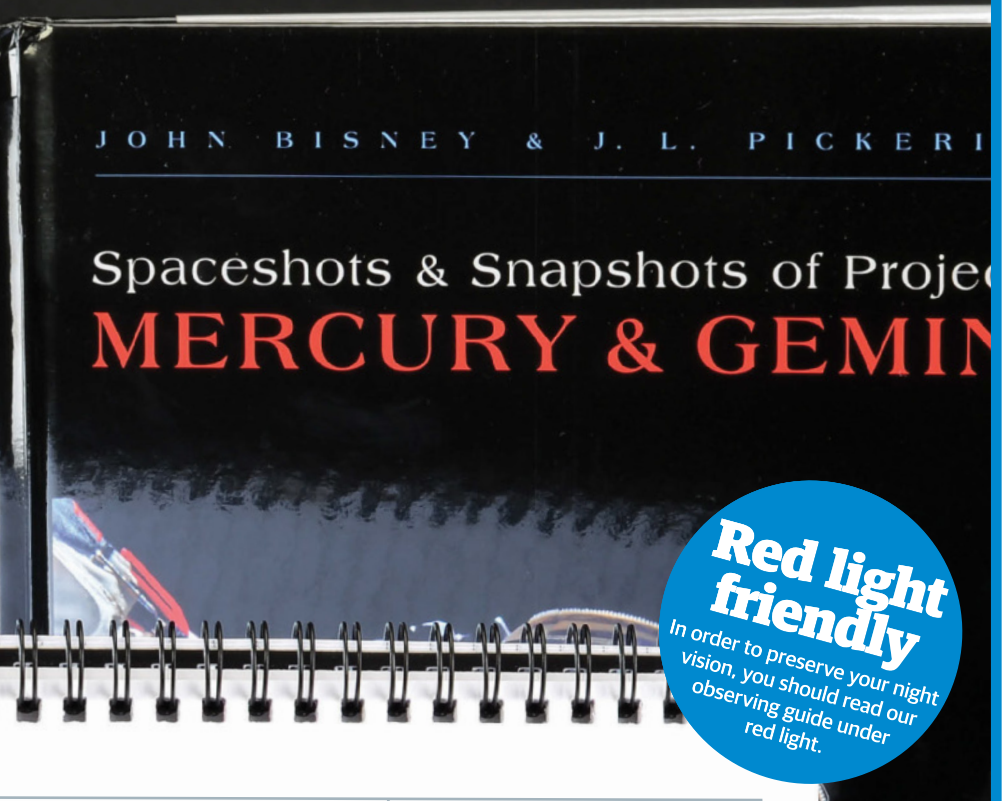
Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

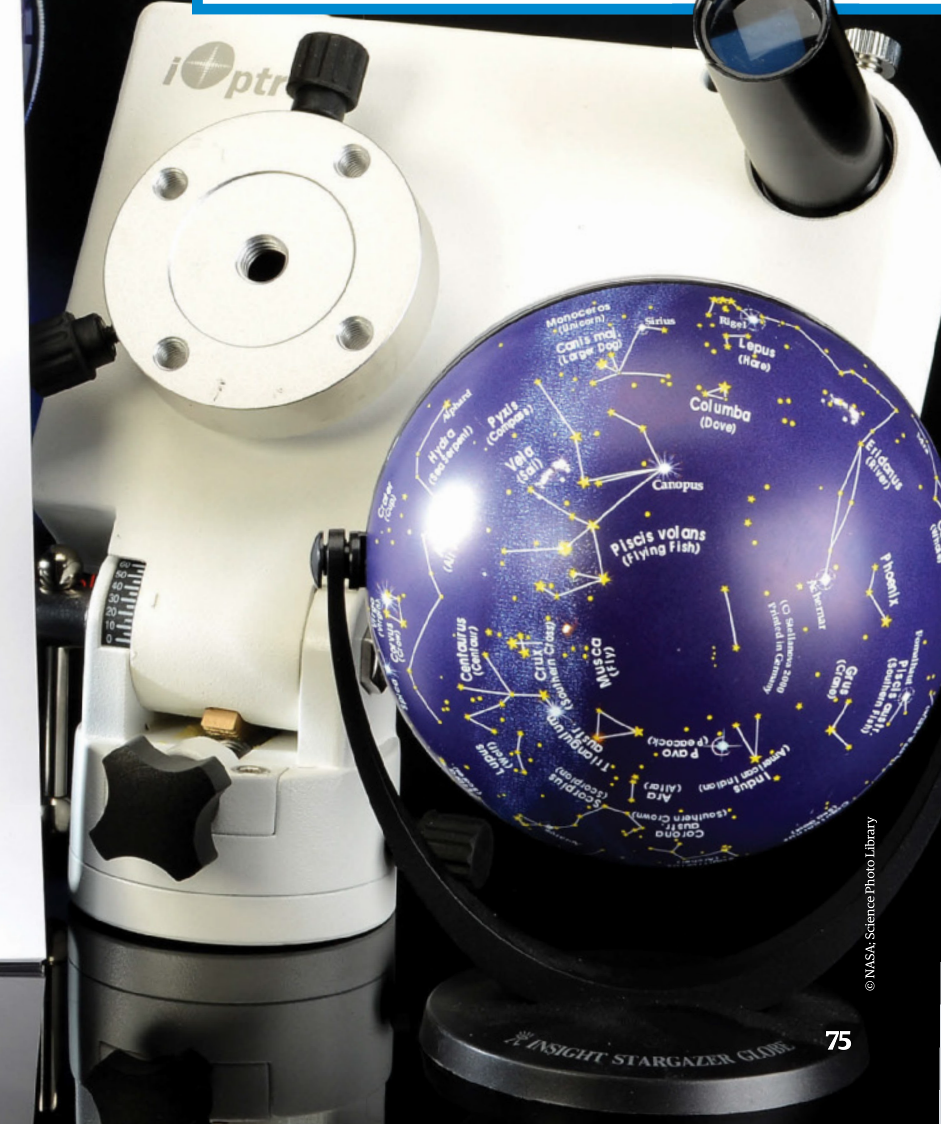
Magnitude
An object's magnitude tells you how bright it will appear from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, an object with a magnitude of -1 is brighter than one with a magnitude of +2.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as Earth rotates, we see different parts of the sky throughout the night.

Declination (Dec)
Declination tells you how high an object will rise in the sky. Like Earth's latitude, declination measures north and south. It is measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.





Red light friendly
In order to preserve your night vision, you should read our observing guide under red light.

11 FEB 👁 The Moon makes its closest approach to Earth

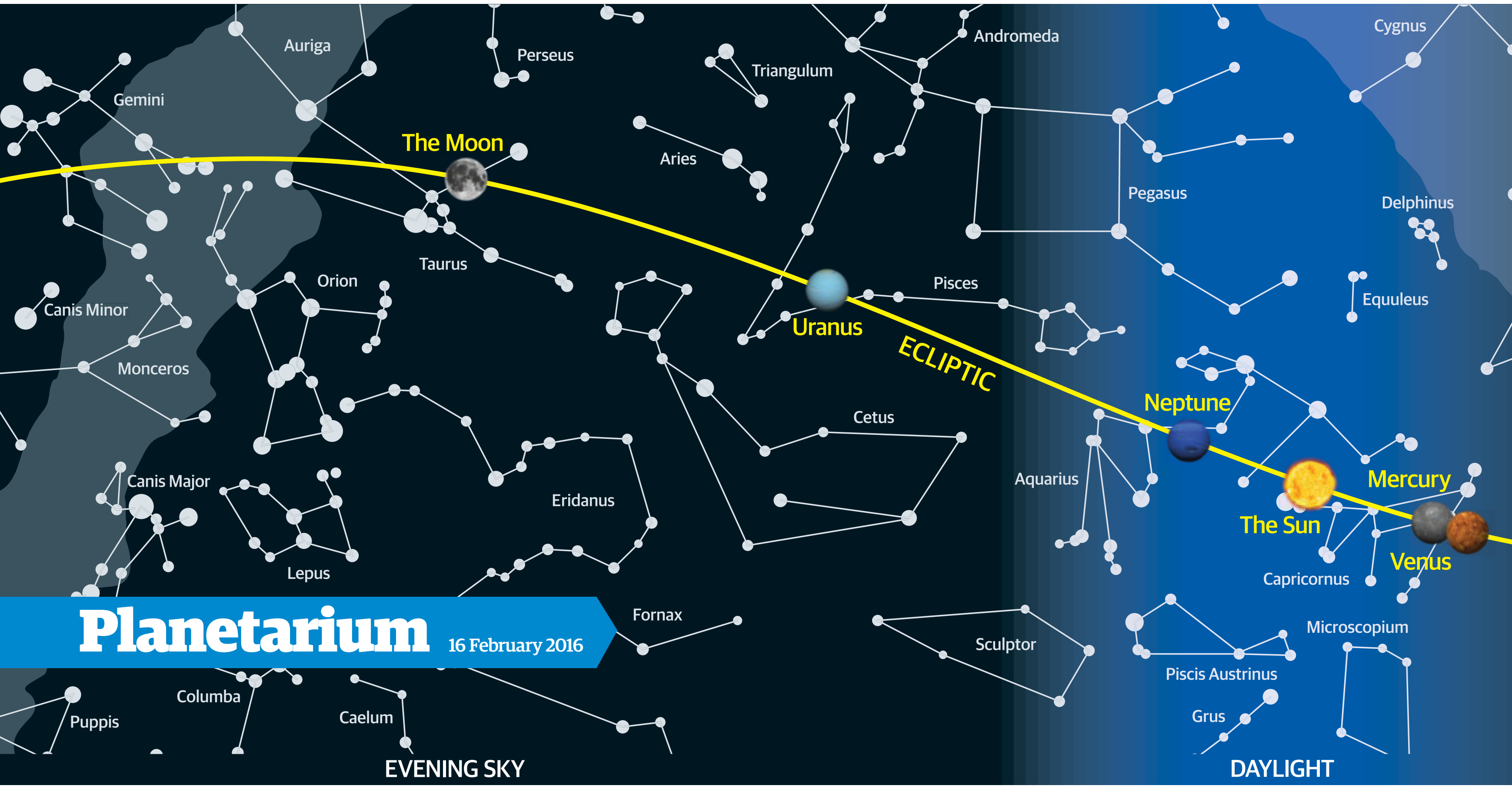
12 FEB 🔭 Conjunction between the Moon and Uranus in Pisces

24 FEB 👁 Conjunction between the Moon and Jupiter in Leo

02 MAR 👁 Conjunction between the Moon and Saturn in Ophiuchus

- 👁 Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

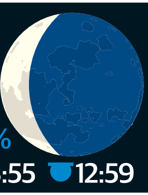
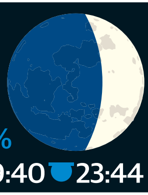
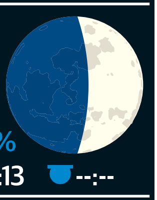
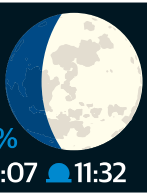
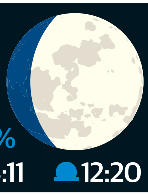
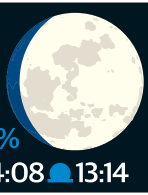
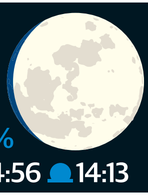
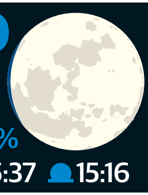
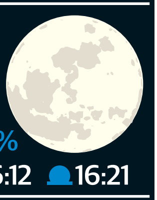
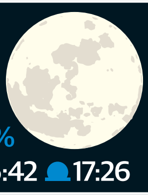
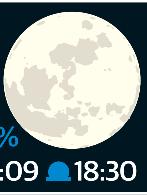
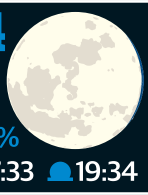
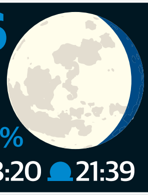
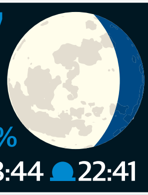
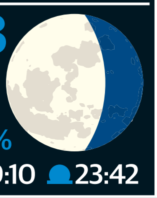
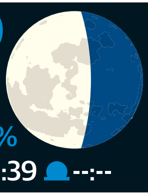
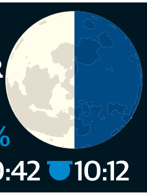
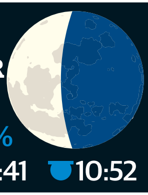
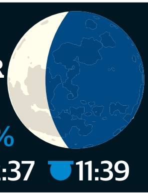
© NASA; Science Photo Library



Planetarium

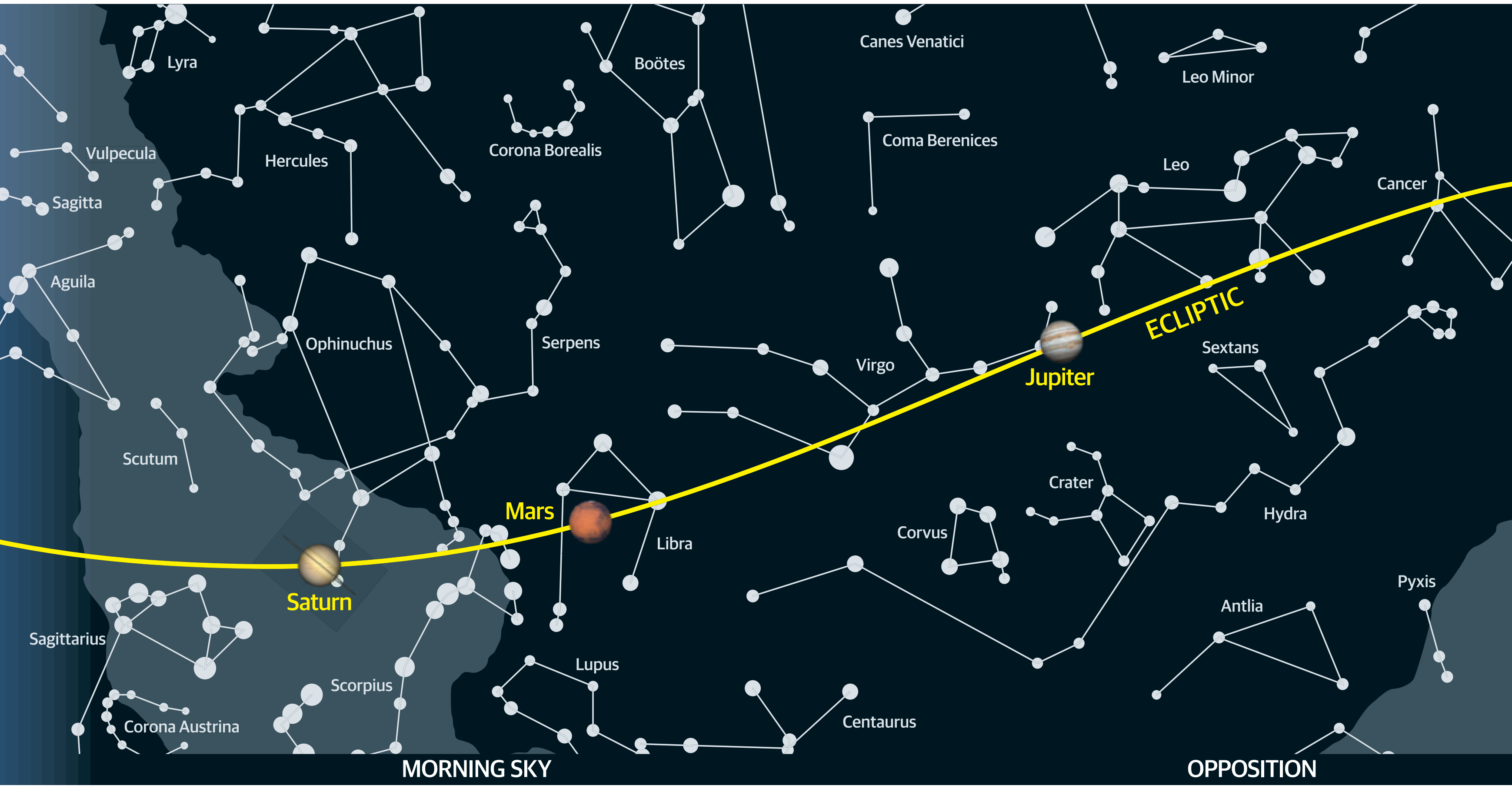
16 February 2016

Moon phases

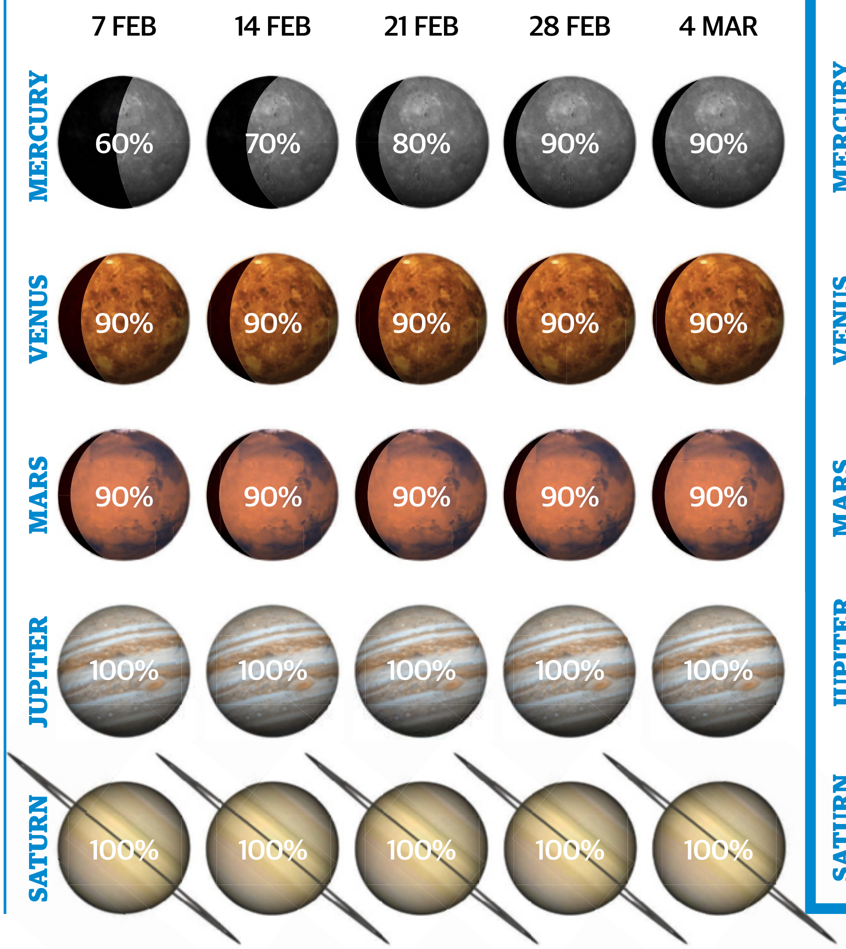
4 FEB		19.4%	◓03:55	◒12:59
5 FEB		12.2%	◓04:50	◒13:51
6 FEB		6.7%	◓05:41	◒14:52
7 FEB		1.8%	◓06:25	◒16:00
8 FEB NM		0.1%	◓07:05	◒17:14
9 FEB		1.2%	◓07:40	◒18:31
10 FEB		5.3%	◓08:11	◒19:50
11 FEB		12.1%	◓08:41	◒21:09
12 FEB		21.2%	◓09:10	◒22:27
13 FEB		31.9%	◓09:40	◒23:44
14 FEB		43.4%	◓10:13	◒--:--
15 FEB FQ		55.1%	◒00:58	◓10:50
16 FEB		66.3%	◒02:07	◓11:32
17 FEB		76.4%	◒03:11	◓12:20
18 FEB		85.0%	◒04:08	◓13:14
19 FEB		91.9%	◒04:56	◓14:13
20 FEB		96.7%	◒05:37	◓15:16
21 FEB		99.4%	◒06:12	◓16:21
22 FEB		99.7%	◒06:42	◓17:26
23 FEB FM		99.9%	◒07:09	◓18:30
24 FEB		98.4%	◒07:33	◓19:34
25 FEB		95.1%	◒07:56	◓20:37
26 FEB		90.0%	◒08:20	◓21:39
27 FEB		83.5%	◒08:44	◓22:41
28 FEB		75.7%	◒09:10	◓23:42
29 FEB		66.9%	◒09:39	◓--:--
1 MAR LQ		57.3%	◓00:42	◒10:12
2 MAR		47.2%	◓01:41	◒10:52
3 MAR		37.0%	◓02:37	◒11:39

%	Illumination
◓	Moonrise time
◒	Moonset time
FM	Full Moon
NM	New Moon
FQ	First quarter
LQ	Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	7 FEB	14 FEB	21 FEB	28 FEB	4 MAR
MERCURY	60%	70%	80%	90%	90%
VENUS	90%	90%	90%	90%	90%
MARS	90%	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%	100%
SATURN	100%	100%	100%	100%	100%

Planet positions

All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	Feb 07	19h 34m	-20° 58'	Sagittarius	-1.9	06:17	14:35
	Feb 14	20h 08m	-20° 34'	Capricornus	-1.8	06:21	14:45
	Feb 21	20h 47m	-19° 10'	Capricornus	-1.7	06:24	15:05
	Feb 28	21h 30m	-16° 43'	Capricornus	-1.7	06:24	15:35
	Mar 04	22h 01m	-14° 20'	Capricornus	-1.7	06:23	15:44
VENUS	Feb 07	19h 14m	-21° 57'	Sagittarius	-4.2	06:04	14:09
	Feb 14	19h 51m	-20° 56'	Sagittarius	-4.1	06:06	14:25
	Feb 21	20h 28m	-19° 25'	Capricornus	-4.1	06:05	14:44
	Feb 28	21h 03m	-17° 26'	Capricornus	-4.1	06:01	15:04
	Mar 04	21h 28m	-16° 27'	Capricornus	-4.1	05:59	15:12
MARS	Feb 07	15h 03m	-15° 43'	Libra	0.3	01:14	10:37
	Feb 14	15h 16m	-16° 38'	Libra	0.2	01:05	10:17
	Feb 21	15h 28m	-17° 27'	Libra	0.0	00:55	09:57
	Feb 28	15h 40m	-18° 12'	Libra	-0.1	00:44	09:37
	Mar 04	15h 48m	-18° 40'	Libra	-0.2	00:35	09:22
JUPITER	Feb 07	11h 31m	+04° 37'	Leo	-2.4	19:54	08:52
	Feb 14	11h 29m	+04° 54'	Leo	-2.4	19:22	08:23
	Feb 21	11h 26m	+05° 14'	Leo	-2.5	18:50	07:55
	Feb 28	11h 23m	+05° 35'	Leo	-2.5	18:18	07:26
	Mar 04	11h 21m	+05° 50'	Leo	-2.5	17:55	07:05
SATURN	Feb 07	16h 53m	-20° 52'	Ophiuchus	1.1	03:36	11:55
	Feb 14	16h 55m	-20° 55'	Ophiuchus	1.1	03:10	11:30
	Feb 21	16h 57m	-20° 57'	Ophiuchus	1.1	02:45	11:04
	Feb 28	16h 58m	-20° 58'	Ophiuchus	1.1	02:19	10:37
	Mar 04	16h 59m	-20° 59'	Ophiuchus	1.1	02:00	10:18

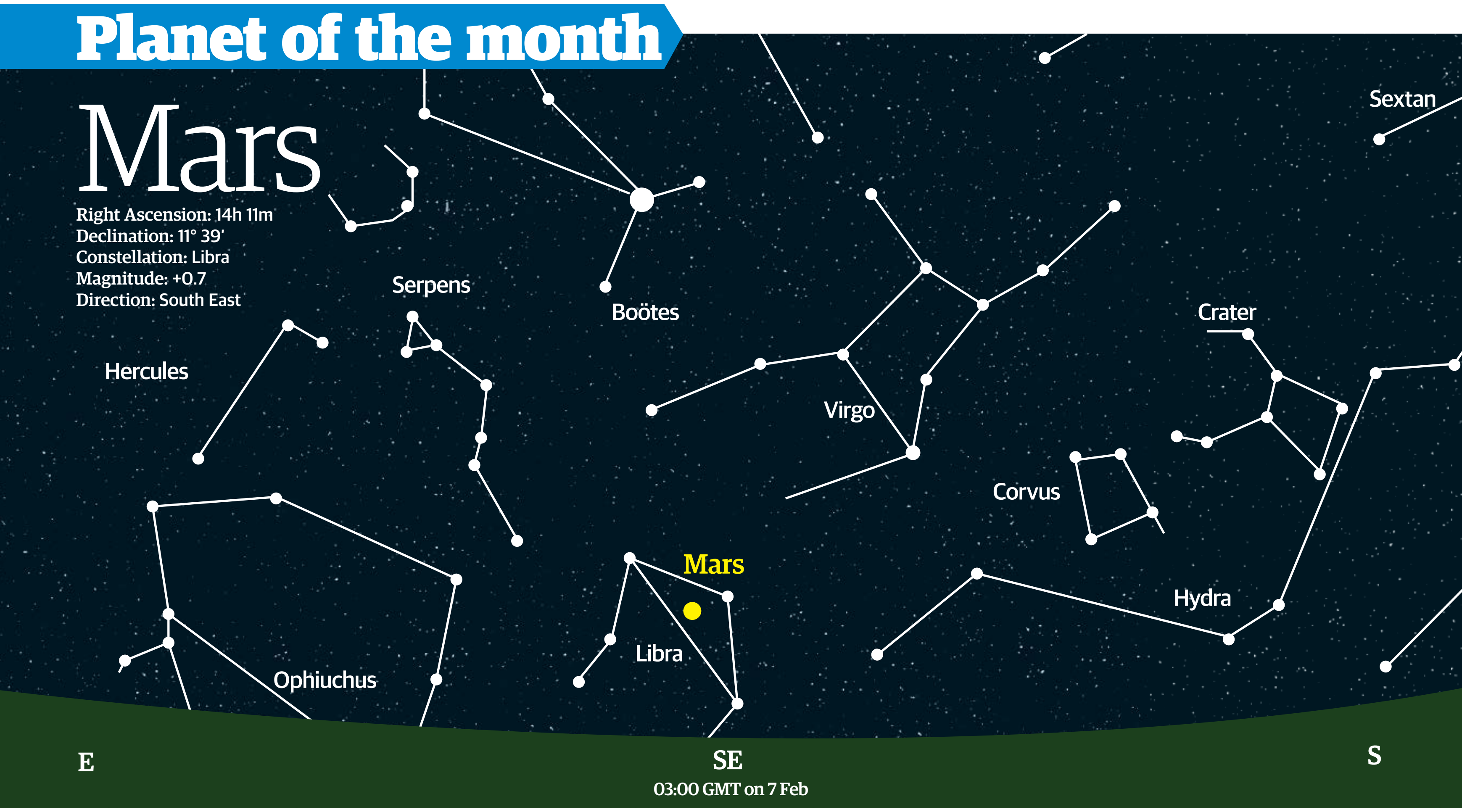
This month's planets

All of the Solar System's bright planets – Jupiter, Mars, Saturn, Venus and Mercury – are splendidly arrayed in the morning skies

Planet of the month

Mars

Right Ascension: 14h 11m
Declination: 11° 39'
Constellation: Libra
Magnitude: +0.7
Direction: South East



03:00 GMT on 7 Feb

On 7 February, Mars is located in mid-Libra some three degrees east of Alpha Librae (Zubenelgenubi, magnitude +2.8). Shining at magnitude +0.7, the planet is pretty easy to spot by now, rising at around 1.15am and culminating due south at an altitude of 23 degrees by 6am. Through the telescope, Mars appears as a small orange disc 7.2 arcseconds in diameter, and it shows quite a pronounced phase, as it is 90 per cent illuminated.

Under good viewing conditions, a 100mm telescope at high magnification (150x or greater) ought to be able to reveal some of Mars' most obvious surface markings, including the bright north polar ice cap and its broader dusky desert markings. Over the ensuing days and weeks, Mars moves slowly eastward through Libra, gradually brightening, while its apparent diameter grows.

By 4 March, the planet makes an obvious visual impact to the unaided eye, appearing as a noticeably orange-hued, ember-like spot in southeastern Libra, shining at magnitude +0.2 – the brightest since mid-July 2014 when the planet was in Virgo.

By now it has grown to an apparent diameter of nine arcseconds, a size that is large enough to reveal some good surface detail. Currently, Mars is slowly turning its northern hemisphere away from us, so features in both the planet's northern and southern hemispheres can be seen quite well during the course of a night's observation.

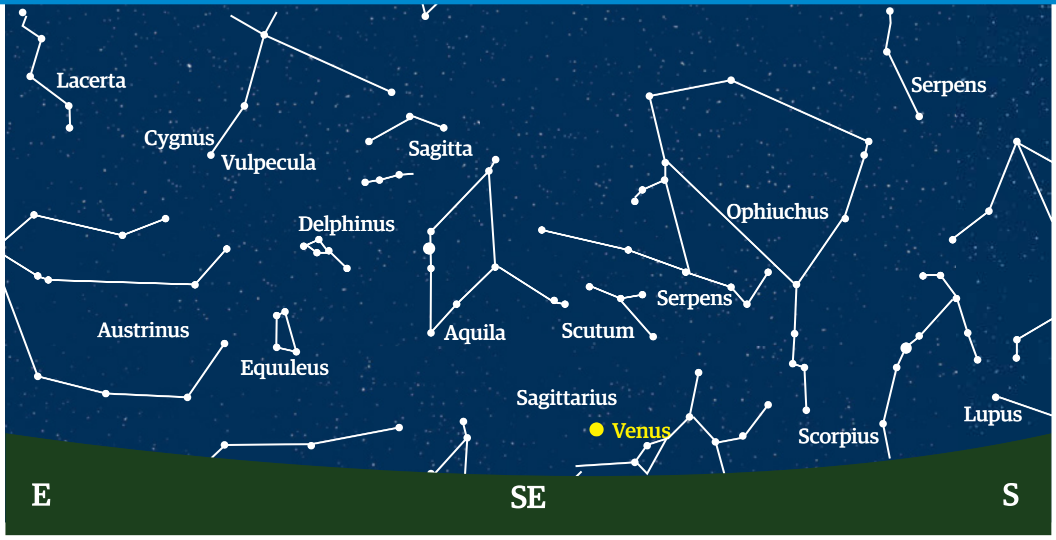
Mars rotates on its axis once every 24.6 hours, and observations separated by an hour or so will easily reveal the planet's rotation. Since the Martian day is slightly longer than a day here on Earth, if Mars is observed at about the same time each successive evening, the planet's rotation will appear to lag behind, with more easterly surface features coming into the view field of view. The difference amounts to around nine degrees of Martian longitude east per day, so a complete tour around the Red Planet can be accomplished in around six weeks if an observation is made at around the same time each clear evening.

Let's take a look at the planet's appearance through the month using a 100mm telescope at high magnification and under good seeing conditions, setting a time of around 3am for each observation. Beginning on 7 February, the Tharsis region (famous for its mighty volcanoes, including Olympus Mons) crosses the planet's central meridian, followed three days later by the famous 'Eye of Mars', Solis Lacus, in Mars' southern hemisphere. The broad, dusky wedge of Mare Acidalium in the north crosses the planet's meridian on 16 February – this is prominent and should be pretty easy to spot.

In the south, Sinus Meridiani (on the planet's zero degree line of longitude) transits the meridian on 19 February, while following it, the bright area of Hellas in the south and the bordering, well-defined and V-shaped dusky Syrtis Major Planum will transit the meridian on 26 February. By 4 March we see the bright volcanic region of Elysium at the centre of the disc and the extensive southern tract of Mare Cimmerium crosses Mars' central meridian.

Venus

07:30 GMT on 7 Feb

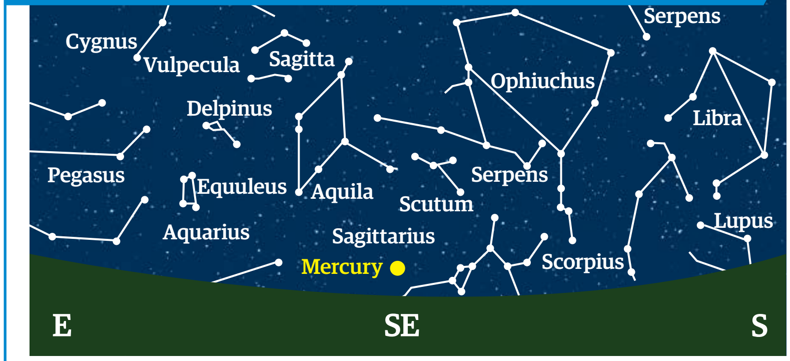


Right Ascension: 16h 56m
Declination: -21° 02'
Constellation: Sagittarius
Magnitude: -4.3
Direction: South East

Venus is a morning object, located west of the Sun, heading closer to the Sun during February. Having risen only a few degrees above the southeastern horizon at sunrise, the planet is not well placed for observation from the UK. On 7 February the planet is eight degrees above the horizon at sunrise, but so bright that you will need an optical aid. By 4 March, Venus is just five degrees above the horizon, located 23 degrees west of the Sun. Telescopically, Venus is 11 arcseconds in apparent diameter and presents a 91 per cent illuminated disc. With superior conjunction on 6 June, this marks the end of Venus' current morning apparition. You'll have to wait until the late autumn to view Venus at a reasonable altitude in evening skies.

Mercury

07:00 GMT on 7 Feb

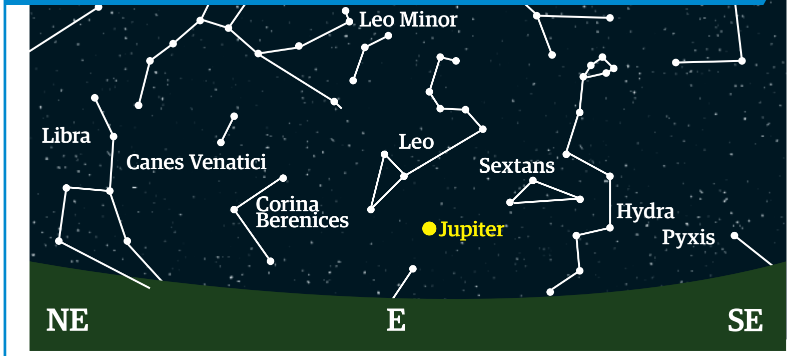


Right Ascension: 19h 51m
Declination: -18° 28'
Constellation: Sagittarius
Magnitude: -0.2
Direction: South East

Mercury is a morning object, located west of the Sun. On the morning of 7 February the planet makes its greatest western elongation, some 25.6 degrees, from the Sun. However, this is a very unfavourable showing of the innermost planet when viewed by observers in the UK, since Mercury is only a degree or so above the horizon at sunrise.

Jupiter

20:30 GMT on 20 Feb

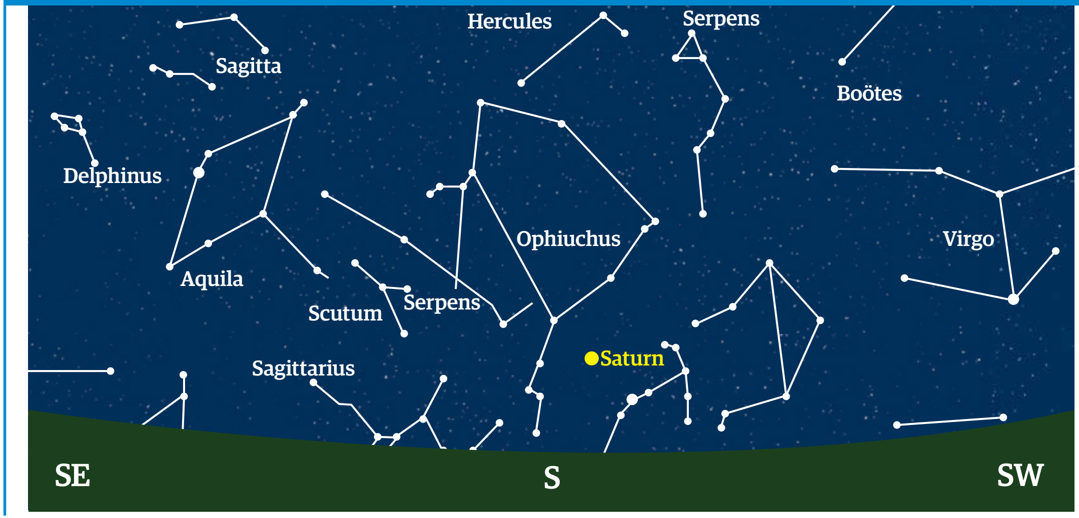


Right Ascension: 11h 35m
Declination: +04° 03'
Constellation: Leo
Magnitude: -2.3
Direction: East

Residing in southeastern Leo, Jupiter moves slowly westward this month. On 7 February Jupiter rises at 8pm and culminates due south at 2.30am at an altitude of 43 degrees. By 4 March the planet is 14 arcminutes south of Sigma Leonis (magnitude +4.0), and transits the meridian at 12.30am. The planet's opposition takes place on 8 March.

Saturn

06:30 GMT on 24 Feb



Right Ascension: 16h 37m
Declination: -20° 24'
Constellation: Ophiuchus
Magnitude: +1.2
Direction: South

On 7 February Saturn rises in the southeast at 3.30am and climbs to 17 degrees above the southern horizon by sunrise at 7.30am. By 4 March, Saturn rises at 2am and is due south at 6am, a good 40 minutes prior to sunrise. Telescopically, Saturn presents a globe 17 arcseconds across; its ring system is wide open and measures 37 arcminutes across at its widest. Note the broad shadow of the planet's disc on the rings, and the visible detail within the rings includes the dark Cassini Division. The planet itself shows some atmospheric detail in the form of belts and zones; particularly prominent is the dusky North Equatorial Belt and the North Polar Region.

@ESO/F.Char

How to...

Shoot a planetary conjunction using a digital camera

It's rewarding to be able to record the visually stunning line ups that occur between the planets. Here's how...

You'll need:

- ✔ DSLR Camera
- ✔ Tripod
- ✔ Remote control shutter

Conjunctions between the planets happen fairly regularly. But some are more spectacular than others. It is great to be able to record them and make them look good in an image. There is, of course, a lot to consider when setting up for that perfect shot.

The first thing to remember is that you are photographing in low light conditions, so you'll need to take your camera off automatic mode and be prepared to experiment with settings. Exposures will need to be longer than in daylight, too, so a tripod will be necessary to give you a good, clean image, free of shakes and wobbles.

You'll also need to frame the picture, so keep in mind not just the planets you are imaging, but also the rest of the shot. Bear in mind that a tree or a mountain can add drama to an image. Longer exposures will be aided by the addition of a remote control shutter release. This will also help to keep the images blur free and detailed.

A zoom lens, or a selection of different focal length lenses will also help make your pictures look good. Don't go too mad here, though! A nightscape image requires a generous amount of foreground and not just a zoomed in frame of two points of light. Framing, composition and foreground put the image into context.

When imaging faint objects, such as planets, it's also helpful to increase the ISO settings on your camera. This increases the sensitivity of the imaging chip, but can also introduce 'noise' into the image, although it does mean that your exposure times can be shorter. In most modern DSLR cameras, images can still look fairly clean with ISO settings of up to 1,000, but use less if you can. An ISO of 400 or 800 are often good settings to use. But be prepared to experiment with this.

Take lots of images! A large memory card is helpful. At twilight, the ambient light is changing constantly, so your settings will have to as well to keep up with the night sky. Make sure your camera's focus is good, too. If you have the ability to magnify the image on your camera's built-in screen, zoom in and tweak the focus to make the stars as small as possible. Experiment with different exposure times and you'll soon realise what looks good. Be prepared to move the camera often, too, to keep reframing the image as the night sky and its objects are continually moving. ■

Tips & tricks

Practice in daylight

Get to know all the manual controls on your camera in daylight so that using them in the dark is easier.

Be aware of dew

Lenses can dew over quickly in the cold night air. Check them regularly to ensure clear, crisp pictures.

Keep batteries warm

Batteries can run flat quite quickly in the cold. Always carry spares in your pocket where it's warm.

Experiment with settings

Take lots of images and change the settings regularly to see if you're able to improve your shots.

Taking successful conjunction images

How to prepare for and image a 'gathering' of planets

When setting up, it's easier to manoeuvre your telescope mount without the scope or counterweight attached. Once you are happy with your alignment, you can add the telescope and counterweights, but be careful not to knock the mount out of alignment as you do this. Make sure the mount is level and adjust each tripod leg as necessary. You can use a small spirit level to help. A polar alignment scope can help, too, if you have one. Don't forget to use a red torch during set up to keep your eyes dark-adapted.

Send your photos to
photos@spaceanswers.com

1 **Be prepared and check your kit**
Preparation is everything. Check batteries, lenses, memory cards and your tripod, especially if you are going to image from a remote site.

2 **Be aware of obstructions**
Make sure that you have a clear view with no obstructions such as trees and houses. Ensure this is the case for the entire time you intend to be imaging.

3 **Try framing your shots**
Set up your camera for the most visual impact. Use foreground objects such as trees to frame the picture and to give the image context.

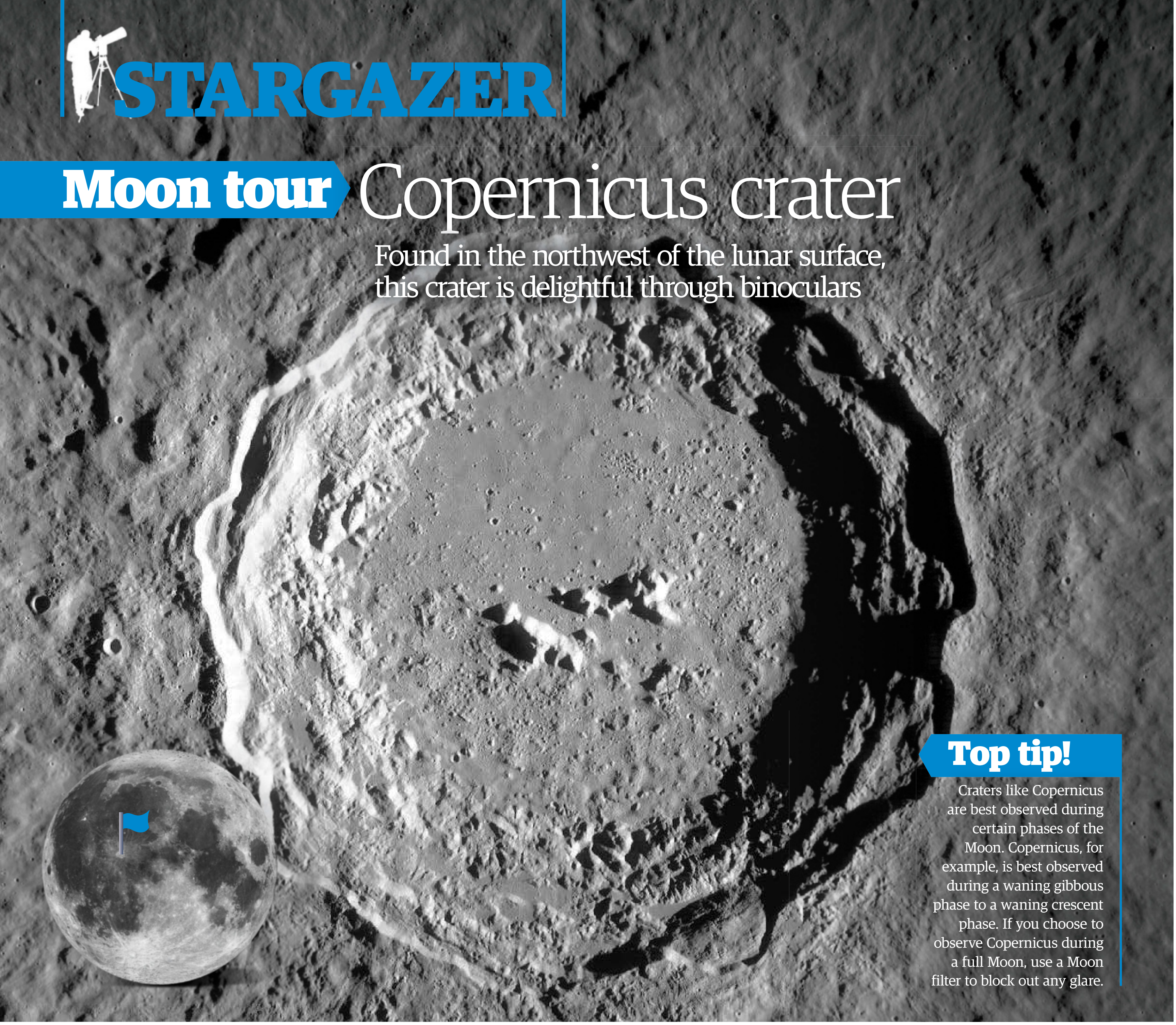
4 **Keep your night vision with red light**
A red light head torch is useful for illuminating camera dials in the dark. It will keep your eyes dark-adapted, therefore preserving your night vision.

5 **Check that your DSLR is focussed**
Keep checking that your camera is well-focussed. It's easy to knock the focusing ring in the dark and ruin a series of images.

6 **Experiment with your camera settings**
Change the settings that you are using after you've taken a few shots. If your images haven't improved, then go back to the previous settings.

Moon tour Copernicus crater

Found in the northwest of the lunar surface, this crater is delightful through binoculars



Top tip!

Craters like Copernicus are best observed during certain phases of the Moon. Copernicus, for example, is best observed during a waning gibbous phase to a waning crescent phase. If you choose to observe Copernicus during a full Moon, use a Moon filter to block out any glare.

One of the most famous of the Moon's bright impact craters – the truly magnificent crater Copernicus – can be marvelled at through your binoculars and telescopes between 17 February and 3 March 2016.

Located around 150 kilometres (93 miles) south of the mountainous border of the Sea of Rains (Mare Imbrium) and lying on the eastern border of the Sea of Isles (Mare Insularum), Copernicus pretty much dominates its local area in the western lunar hemisphere. Indeed, the crater and its surroundings are even so bright that any keen-eyed observer can see it without using an optical aid when it is illuminated by a relatively high Sun (say at full Moon).

Blasted clean out of the Moon's crust by an enormously powerful asteroid impact around 900 million years ago, Copernicus most certainly ranks as one of the most impressive young impact craters in the entire Solar System. An impressive 93 kilometres (58 miles) across, it has a sharp, well-defined rim rising 900 metres (2,953 feet) above its surrounding landscape. Sunk by more than 3,500 metres (11,483 feet) beneath the rim, the crater's floor is overseen by a small central group of mountains, the highest of which rises above 1,000 metres (3,281 feet).

Small telescopes (60mm or smaller) will give the impression that the floor surrounding Copernicus' central peaks appears pretty smooth and dark. However, larger instruments, especially used at high magnification when the lighting is right, will reveal that the crater's southern floor is far more jumbled and hilly than the north. Actually, the entire floor surrounding the central mountains is covered with rock that melted during the impact that formed Copernicus. Like many of the Moon's large craters, Copernicus' inner walls show distinct 'terracing' – a series of concentric stepped levels that were produced as a result of landslides in the crust, following the crater's formation.

Copernicus' outer slopes consist of hills, furrows and radial ridges, formed when the shock waves of the original impact were frozen into the rock and later modified by landslides. Radial ridges further out are made up of piles of material ejected by the original impact. At a greater distance, bright radial rays are arrayed in all directions from the crater, some for many hundreds of kilometres or miles across the surrounding regions.

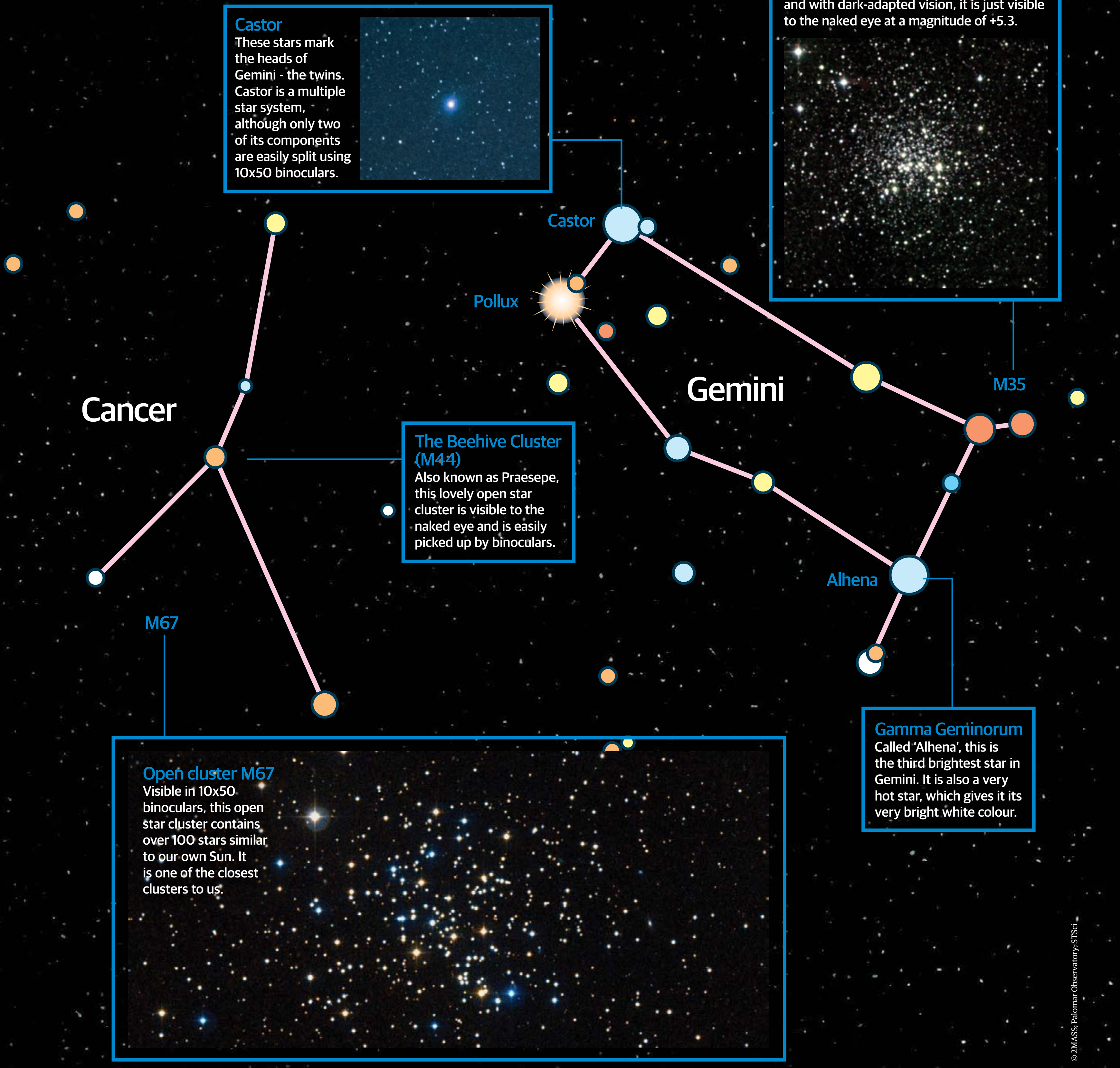
Viewed through a telescope, Copernicus and its surroundings are thrilling. The best time to see the crater is on the evening of 17 February, when the crater is lit by an early morning Sun. It's eastern rim casts a shadow around a quarter of the way across the crater floor; the crater's central mountains are easily seen, and much detail can be discerned on its terraced inner west wall.

As the Sun climbs higher the shadow recedes, but the Copernicus crater remains a prominent feature throughout the evening. On the morning of 3 March, the crater is about to be enveloped by the Moon's sunset terminator; the crater's western rim is extremely prominent, while its floor is completely covered with the encroaching shadow. ■

© NASA

This month's naked eye targets

Feast your eyes on February's offering of stars and open clusters



Castor
These stars mark the heads of Gemini - the twins. Castor is a multiple star system, although only two of its components are easily split using 10x50 binoculars.

Open cluster M35
In binoculars, this star cluster looks like a tight ball of stars. For those under dark skies, and with dark-adapted vision, it is just visible to the naked eye at a magnitude of +5.3.

The Beehive Cluster (M44)
Also known as Praesepe, this lovely open star cluster is visible to the naked eye and is easily picked up by binoculars.

Gamma Geminorum
Called 'Alhena', this is the third brightest star in Gemini. It is also a very hot star, which gives it its very bright white colour.

Open cluster M67
Visible in 10x50 binoculars, this open star cluster contains over 100 stars similar to our own Sun. It is one of the closest clusters to us.

© 2MASS; Palomar Observatory; STScI

How to...

Observe Comet Ikeya-Murakami

Comets are always wonderful objects to have in our skies. This month offers a possible bright one

@ SPL

You'll need:

- ✔ Binoculars
- ✔ Telescope
- ✔ Low power eyepiece
- ✔ Star chart

Comets are arguably among one of the most amazing sights in the night sky. Even the faint ones, which require a telescope to see, are impressive. They are also notoriously unpredictable!

Whereas many comets take hundreds, if not thousands, of years to orbit the Sun, Comet P/2010 V1 Ikeya-Murakami, to give it its correct title, is a short period comet, which means that it is in a fairly close orbit around the Sun and therefore can be seen regularly. It swings by the Sun every 5.29 years and this is when we have a chance of seeing it, because of the heat and the solar wind - a stream of high-energy particles that stream away from the Sun. It will make its closest approach to the Sun at a distance of 1.58 AU on 10 March 2016 - that's just over 1.5 times the distance of the Earth from the Sun.

It is thought that it will be at its brightest around the end of February, although you will probably still need binoculars to be able to see it. However, we just can't be sure. Comets are very unpredictable and can go into outburst at almost any time, although this is more likely to happen when it approaches perihelion, the point when it is closest to the Sun.

So, when is the best time to see it and how do you find it? Comet P/2010 V1 Ikeya-Murakami spends most of February and March in the constellation of Leo, not far above the head of the Lion. Because comets' positions noticeably move over the course of days, if not hours, it's best to use a finder chart to locate it easily. You can find these on the internet. If you don't wish to print out a chart, you can, of course, note the comet's position on an ordinary star chart and take this with you to the telescope.

It will be available to view for most of the night. On the 29 February, the comet is approximately on an imaginary line from Adhafera and Rasalas in Leo's head and is the same distance as between the two stars. It is best to hunt for the comet when there is no Moon nearby, as it drowns out fainter details. It's hoped that the comet may appear considerably brighter than expected. ■

Tips & tricks

Use the internet

Put the name of the comet into one of the major search engines. You'll get the latest information on its whereabouts.

Be patient

Comets can be faint. If you can't find it one night, try again the next night.

Avoid the Moon

Look for the comet on Moonless nights. The light from the Moon can drown out faint objects such as comets.

Seek dark skies

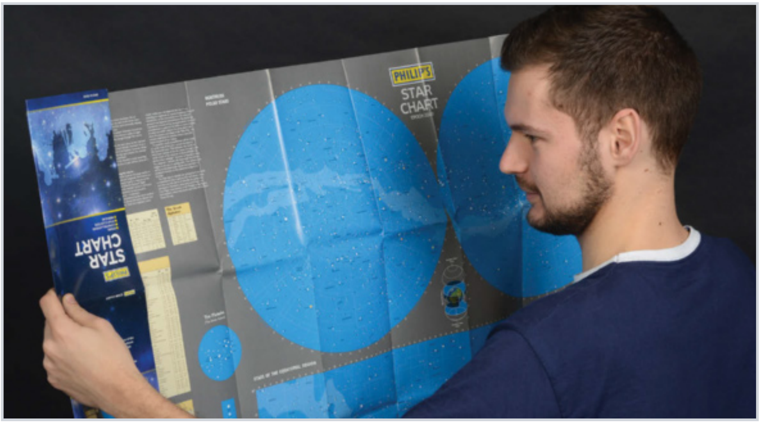
A dark-sky site away from town and city lights will help you to find the comet.

Tracking the comet down

Comets can be faint but still rewarding to see or photograph

To give yourself the best possible chance of seeing P/2010 V1, you will need to know its position, so a finder chart is almost essential, unless it turns out to be really bright! You can find suitable charts on the internet, which will give an accurate position for the object. If you are using a telescope, use a low power, wide field eyepiece. Some comets can show up well with the use of filters. Experiment with UHC or OIII filters or even better, if you have one, a 'Swan Band' filter, which will enhance the dust tail of the comet.

Send your photos to
photos@spaceanswers.com



1 **Use a finderchart**
You should use a finder chart in order to locate Comet P/2010 V1 and use it with your telescope. Most charts will supply coordinates to assist further.

2 **Wait for your eyes to adjust to the dark**
Ensure your eyes are dark-adapted to keep your eyes sensitive to fainter night-sky objects. Avoid bright lights for at least 20 minutes before viewing.

3 **Observe on a Moonless night**
Have an idea of the Moon's rise and set times - its bright disc can wash out even fairly bright objects if it is located in the same part of the night sky.

4 **Ensure that you have stable viewing conditions**
If you are using binoculars, hold them as steady as possible or use a tripod and bracket for optimum stability and superior viewing.

5 **The larger the aperture, the better**
A telescope that's at least six-inches (150mm) in size is ideal for comets. Larger apertures collect more light, offering better views of faint targets.

6 **Use filters to assist with your observations**
If you are using a telescope and have some more specialist filters, try them out. The best one for viewing a comet is a Swan Band filter.

Deep sky challenge

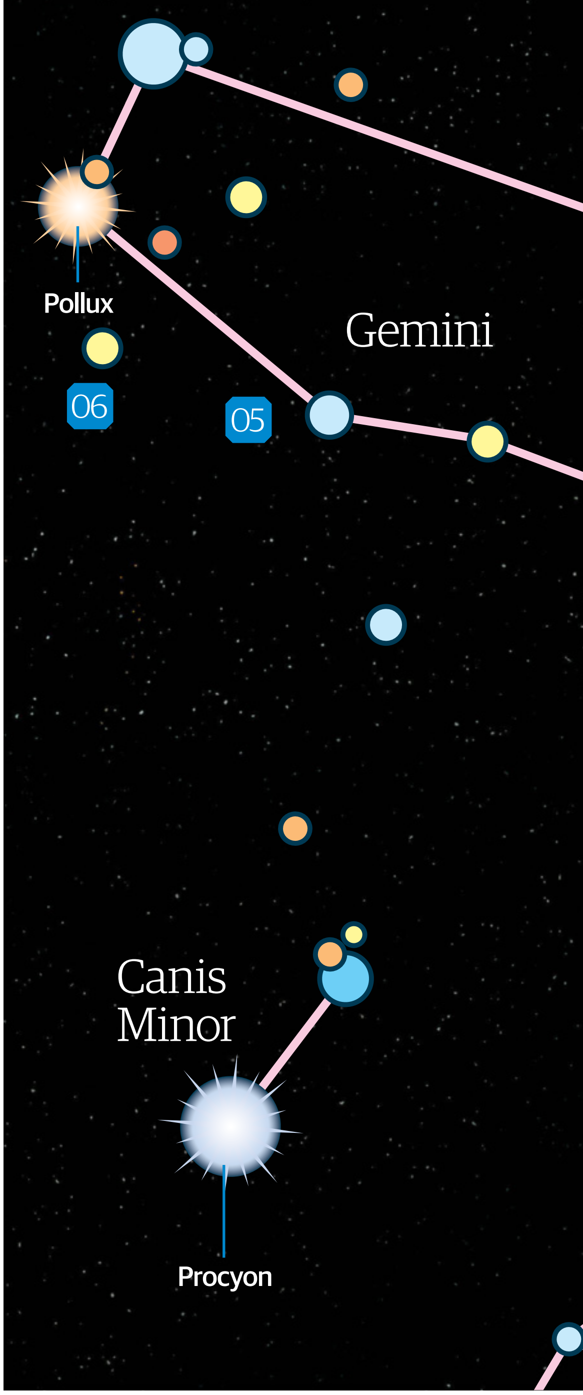
Nebulae and clusters of Gemini, Monoceros and Orion

The constellations in the February skies offer some great sights for those with telescopes

The constellations of Gemini, Monoceros and Orion contain some wonderful objects for those armed with a telescope. Some are nice easy open star clusters, but others are more challenging and may require some patience and the right conditions in order to be seen.

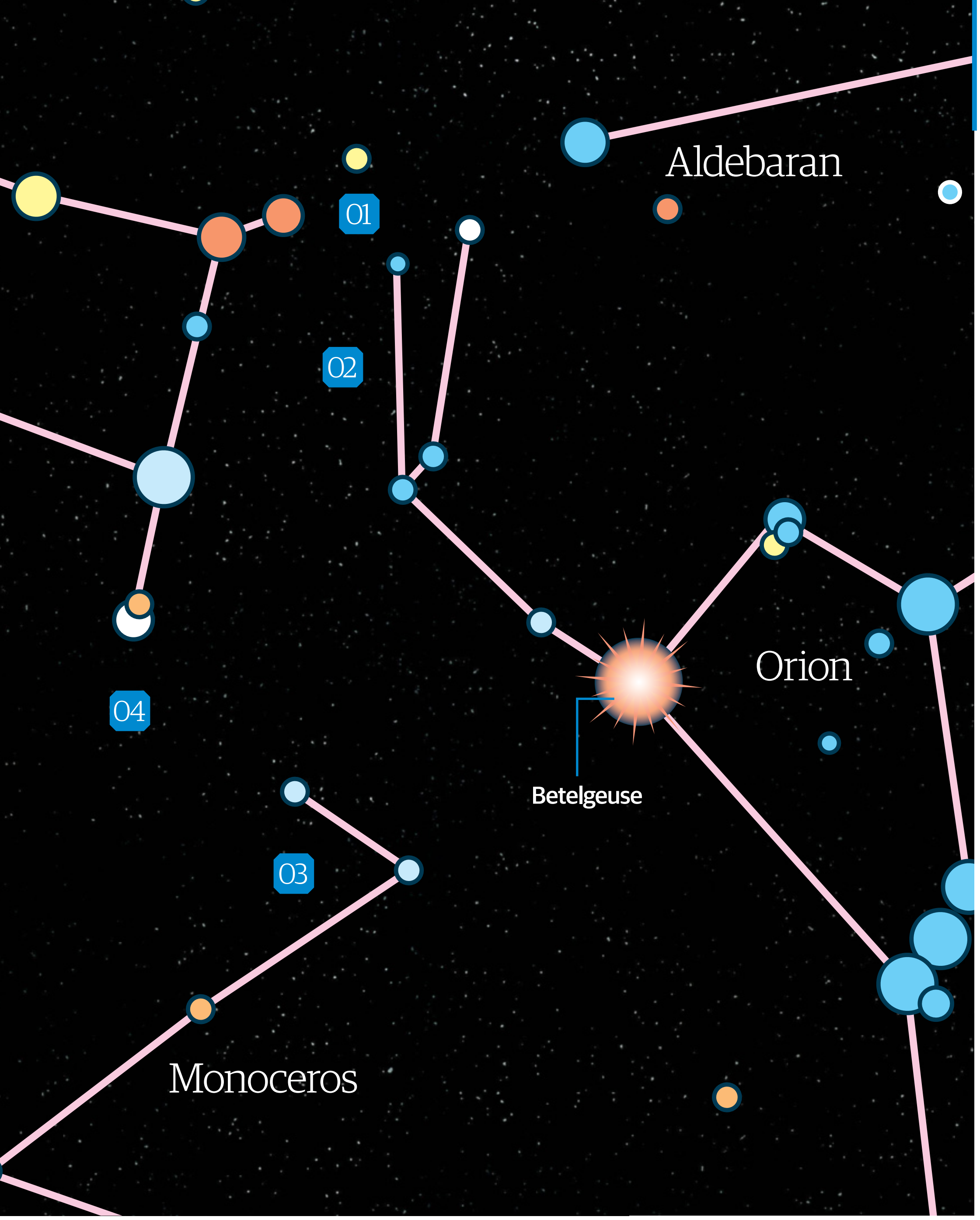
The faint band of the Milky Way sweeps past the feet of the Twins and contains some lovely star clusters and nebulae. The nebulae in particular can be challenging, but are well worth the effort. It's best to observe them when they are highest in the sky, as you will be looking through less of Earth's atmosphere. A UHC filter can help if you have one.

Take your time, a quick look will probably not show anything. For faint objects, use 'averted vision', where you don't look directly at the object but, instead, look slightly away from it while continuing to concentrate on the object. This way the light falls onto the most sensitive part of your retina. Don't give up! If you don't succeed on one night, try again another night. This will also help to train your eyes.



The Cone Nebula (NGC 2264)

The Rosette Nebula and NGC 2244



1 NGC 2129

A small but attractive star cluster, which lies close to the star 1 Geminorum. Two highly luminous B-type supergiants dominate the cluster.

2 NGC 2175 (OCL 476)

Within the boundary of the constellation of Orion, this star cluster is embedded the visually challenging Monkey Head Nebula.

3 The Rosette Nebula and NGC 2244

Another nebula and star cluster combination. The cluster is easy to view in almost any telescope, but the famous Rosette Nebula is much harder to capture visually - a UHC filter will help.

4 The Cone Nebula (NGC 2264)

The Cone Nebula, or NGC 2264, is another nebula with a star cluster embedded within it. It shows up well in long-exposure images but can be tricky visually to make out to the untrained eye.

5 The Eskimo Nebula (NGC 2392)

This faint planetary nebula will need a large aperture telescope to be seen effectively. For the best views, use an OIII filter.

6 NGC 2420

This sparse, open cluster is a challenge through small telescopes and requires a magnification of about 120x. NGC 2420 is best viewed through a telescope with a large aperture.

The Eskimo Nebula (NGC 2392)

NGC 2175

© NASA; ESA; Hubble; JPL-Caltech; University of Arizona

The Northern Hemisphere

With winter well underway, there's a glut of night-sky objects available to observe

Throughout February and early March, observers using the naked eye, binoculars or a telescope will be treated to a variety of night-sky targets after 5pm. The Orion Nebula (M42), which glows at magnitude +4 in the constellation of Orion, makes an excellent target for binoculars or a telescope, while the +3.44-magnitude Andromeda Galaxy (M31) is just visible to the naked eye from dark-sky sites and through telescopes and binoculars in urban regions. The circumpolar galaxies of Ursa Major, which includes the Pinwheel Galaxy (M101), are choice objects for deep-sky enthusiasts keen to observe in the early evening. At varying times of the night, the naked-eye planets will make their way along the ecliptic. Use this map under red light in order to preserve your night vision.

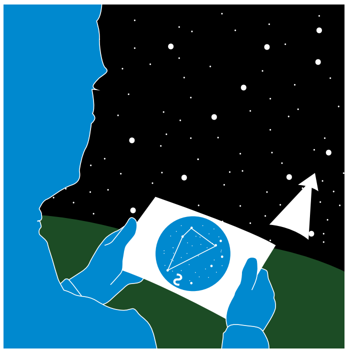
Using the sky chart

This chart is for midnight mid-month and is set for 45° latitude north or south respectively.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.



Magnitudes

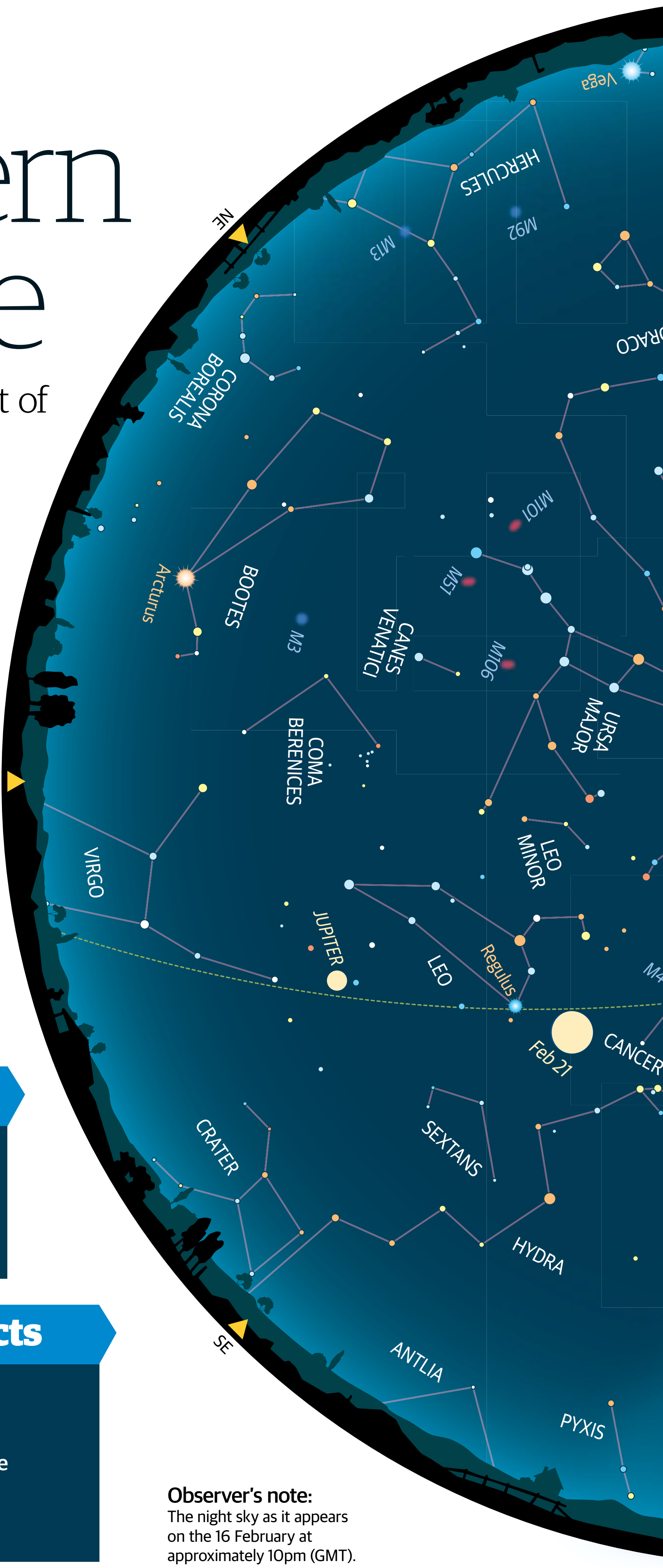
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

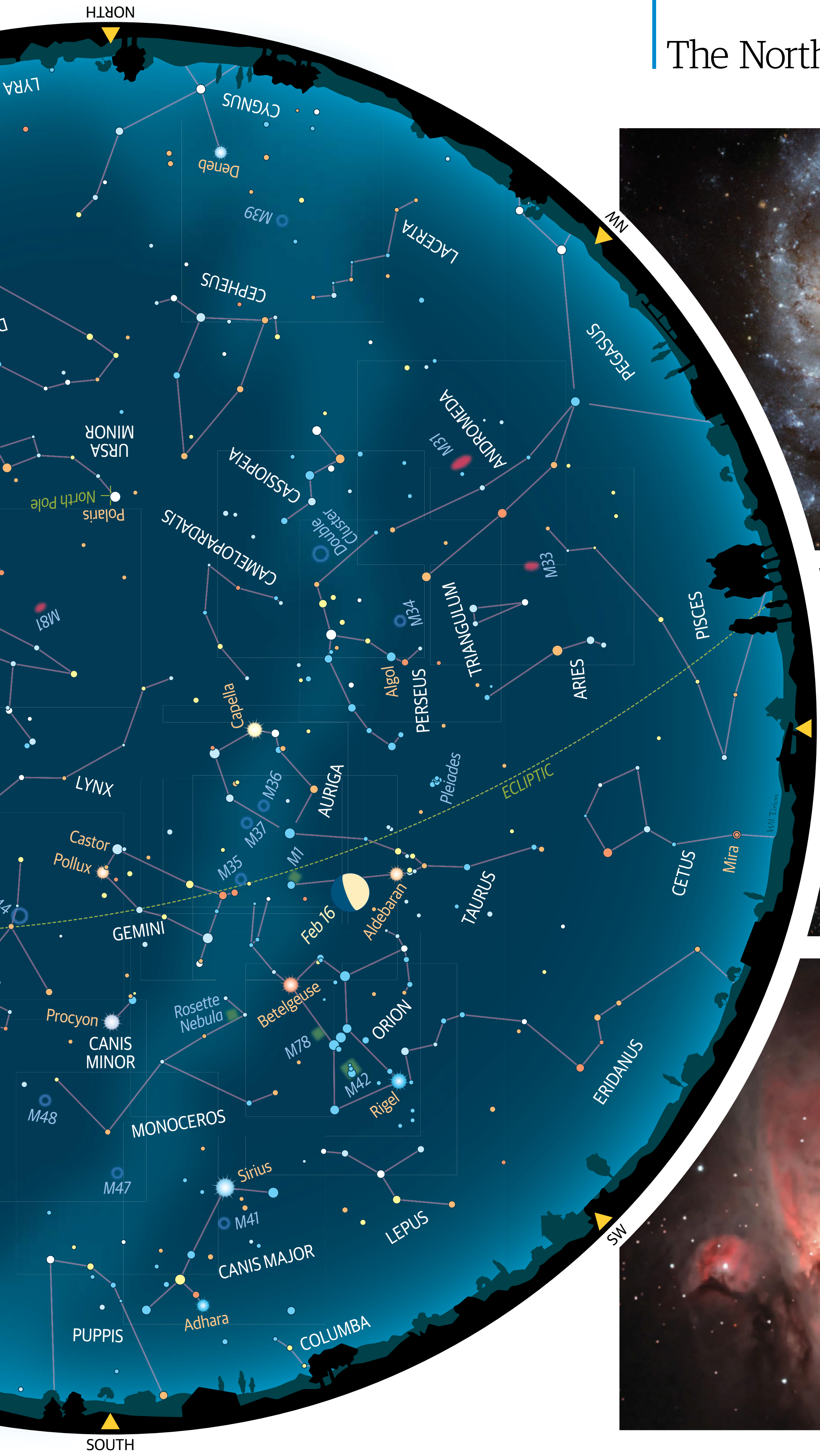
- O-B
- A
- F
- G
- K
- M

Deep-sky objects

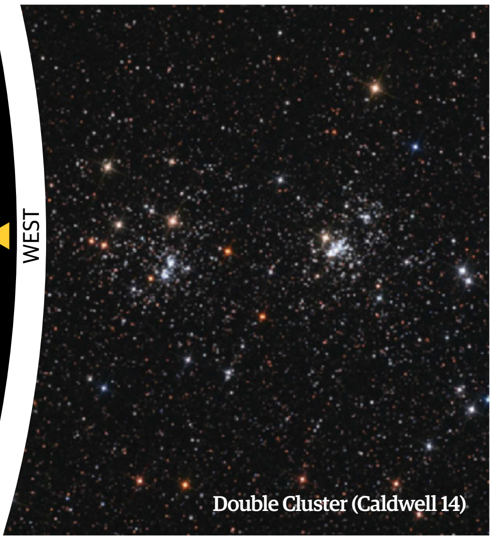
- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on the 16 February at approximately 10pm (GMT).



The Pinwheel Galaxy (M101)


Double Cluster (Caldwell 14)

The Orion Nebula (M42)

© Wil Tirion; NASA

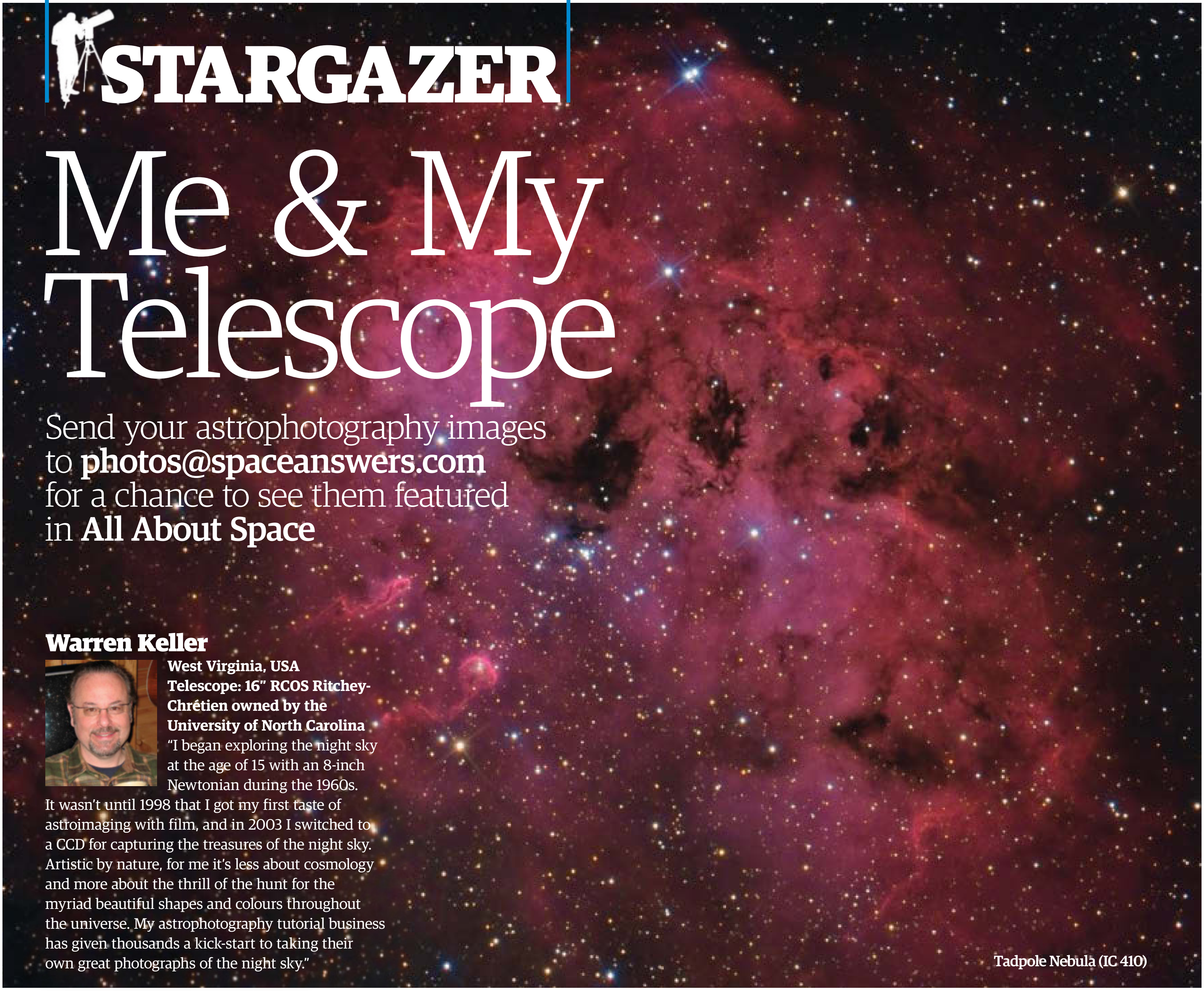
Me & My Telescope

Send your astrophotography images to **photos@spaceanswers.com** for a chance to see them featured in **All About Space**

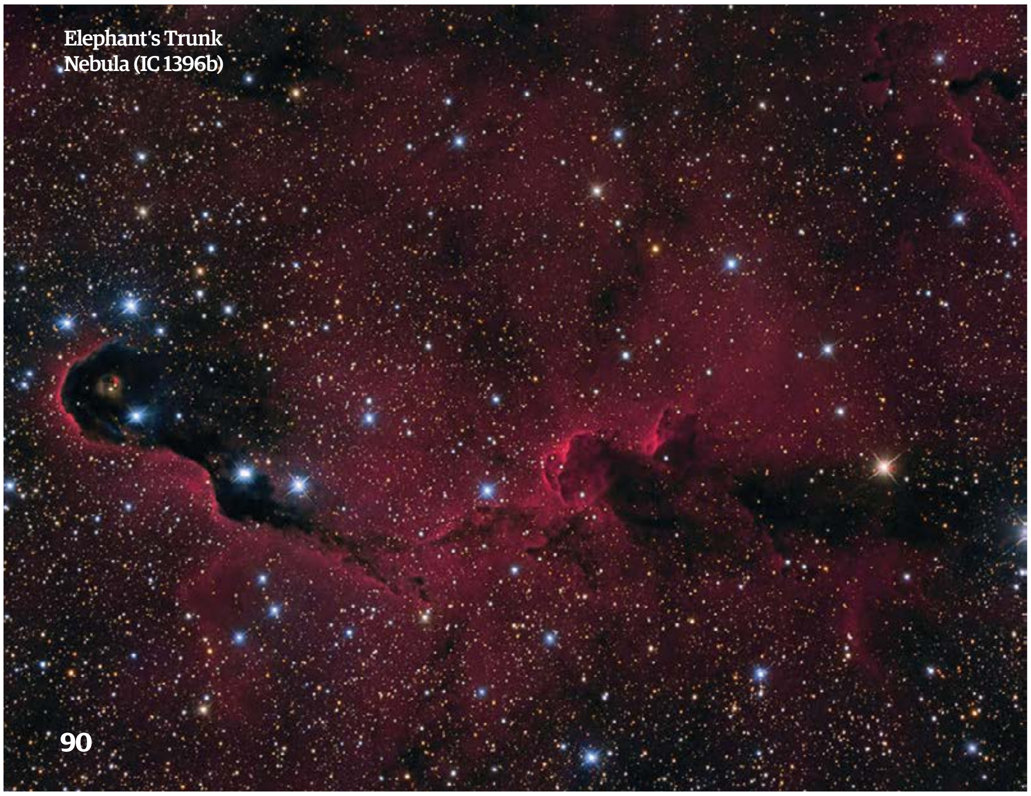
Warren Keller

West Virginia, USA
Telescope: 16" RCOS Ritchey-Chrétien owned by the University of North Carolina

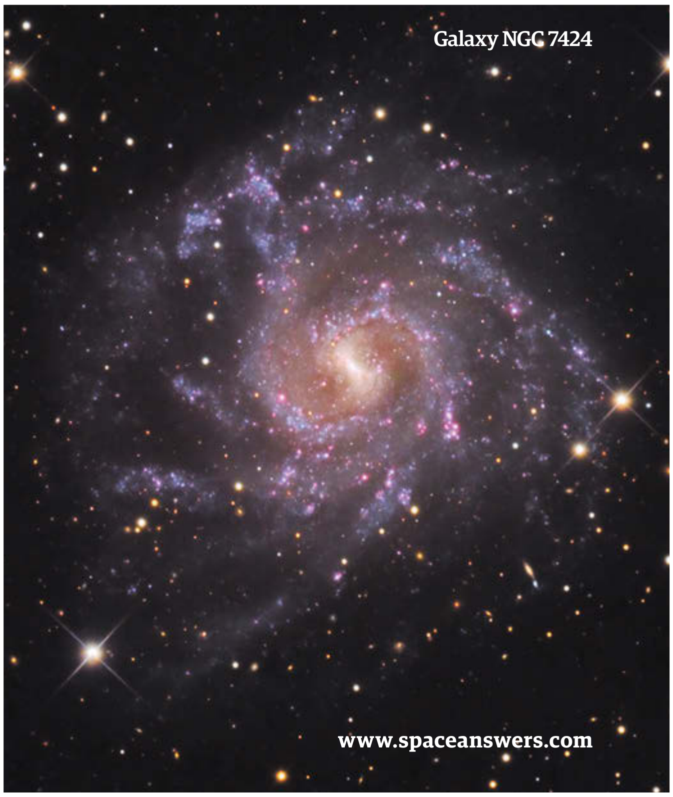
"I began exploring the night sky at the age of 15 with an 8-inch Newtonian during the 1960s. It wasn't until 1998 that I got my first taste of astroimaging with film, and in 2003 I switched to a CCD for capturing the treasures of the night sky. Artistic by nature, for me it's less about cosmology and more about the thrill of the hunt for the myriad beautiful shapes and colours throughout the universe. My astrophotography tutorial business has given thousands a kick-start to taking their own great photographs of the night sky."



Tadpole Nebula (IC 410)



Elephant's Trunk Nebula (IC 1396b)



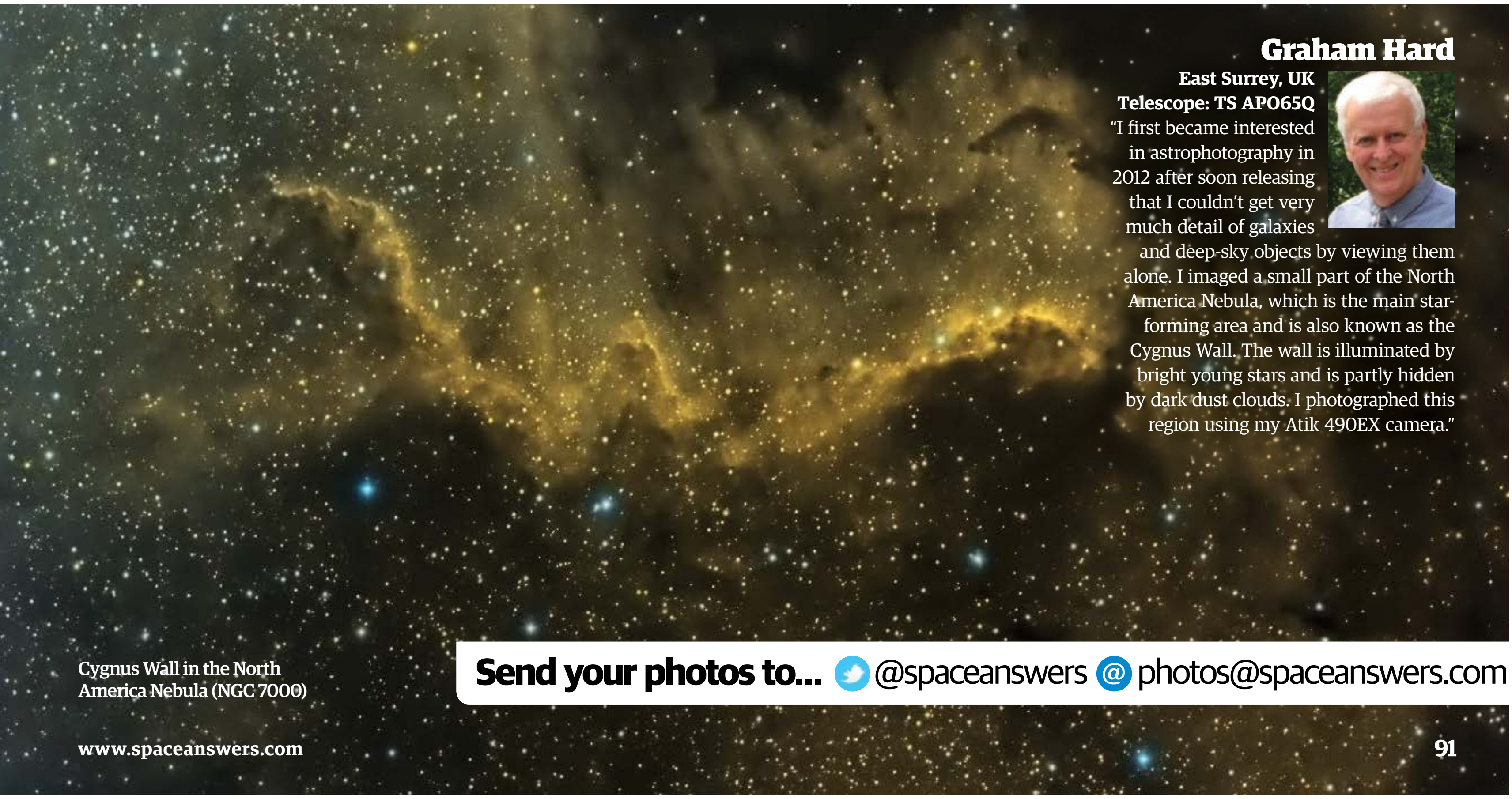
Galaxy NGC 7424

Milky Way above the Persian Gulf, Iran

Amir Shahcheraghian

Port of Mogham, Iran

"My passion for astronomy began in my childhood and ignited my interest in night-sky astrophotography. I enjoy nothing more than setting up a DSLR camera on a tripod and taking images of the night sky and I try to photograph the many objects found in the sky. In order to capture as many night-sky targets as I can, I travel around Iran and shoot from a variety of locations from deserts to mountains."



Graham Hard

East Surrey, UK

Telescope: TS APO65Q

"I first became interested in astrophotography in 2012 after soon releasing that I couldn't get very much detail of galaxies and deep-sky objects by viewing them alone. I imaged a small part of the North America Nebula, which is the main star-forming area and is also known as the Cygnus Wall. The wall is illuminated by bright young stars and is partly hidden by dark dust clouds. I photographed this region using my Atik 490EX camera."

Cygnus Wall in the North America Nebula (NGC 7000)

Send your photos to... @spaceanswers @ photos@spaceanswers.com

Celestron CPC 800 GPS (XLT)

Ideal for the serious astrophotographer, this superb instrument is a must-have for those looking to upgrade on a beginner scope

Telescope advice

Cost: £1,999 ($2,843)
From: David Hinds Ltd
Type: Schmidt-Cassegrain
Aperture: 8"
Focal length: 80"

Best for...

- Intermediate
- Large budget
- Planetary viewing
- Lunar viewing
- Deep-sky objects
- Astrophotography

With the CPC 800, you certainly get what you pay for. An incredibly well-made instrument, this beautifully-presented and, what appears to be a robust telescope on first impressions, is ideal for those looking to upgrade on a beginner's telescope or for those looking for an all-rounder that allows astronomers to get their teeth into some serious astrophotography.

The CPC 800 may look daunting to set up to some, however, Celestron have provided in-depth instructions for fuss-free construction, leaving the user fully guided through the process. The scope will take more than a few minutes to set up, but this is to be expected - especially if you have never put together a computerised instrument. However, on the whole, we do think that the general set up is easy, thanks to the excellent design. Sadly, with the massive amount of rain that the UK has experienced throughout January, we waited quite some time for a sufficiently clear night to test the CPC 800's mettle on a variety of night-sky targets. We were rewarded though, and positioned the Schmidt-Cassegrain under a dark sky on a very chilly winter evening.

As expected - and as it is comprised mostly of steel - the CPC 800 is quite heavy, weighing in at 34 kilograms (74 pounds). While the fork mount makes lifting the scope that touch easier over others, we recommend getting someone to help you carry it to your chosen observing site, or transporting it in a car. While it's quite easy to see the heftiness as a negative, many - if not all - astronomers will be thankful of this: even with a prevalent icy breeze, the telescope stood impressively still. With the constellations of Ursa Major, Leo, Virgo and Ursa Minor in the sky, we couldn't wait to view their many deep-sky treasures using the 8-inch aperture of the CPC 800.

Before we could tour the night sky, we had to use the SkyAlign technology in order to align the telescope for what Celestron state is a "fast and easy alignment process". We couldn't have been more impressed with this feature - simply pick three bright objects in the sky (these can be the Moon, planets or stars) and the telescope's computer system does the work for you. While the experience was a painless one, we do think that a red dot finder during the alignment

The StarBright XLT coating ensures that targets are crystal clear and bright when viewed through the eyepiece

The CPC 800 is supplied with a 40mm eyepiece that gives a magnification of 51x

A red dot finder would be better suited to this telescope over a terrestrial finderscope

“Even with a prevalent icy breeze, the CPC 800 stood impressively still”

process would have been more useful - terrestrial finderscopes (of which this scope has a 8x50 one) can often be problematic. We discovered that the telescope's GPS was turned off, but took no more than a few minutes for the system to figure out our position. Users of the telescope also need to set daylight saving time.

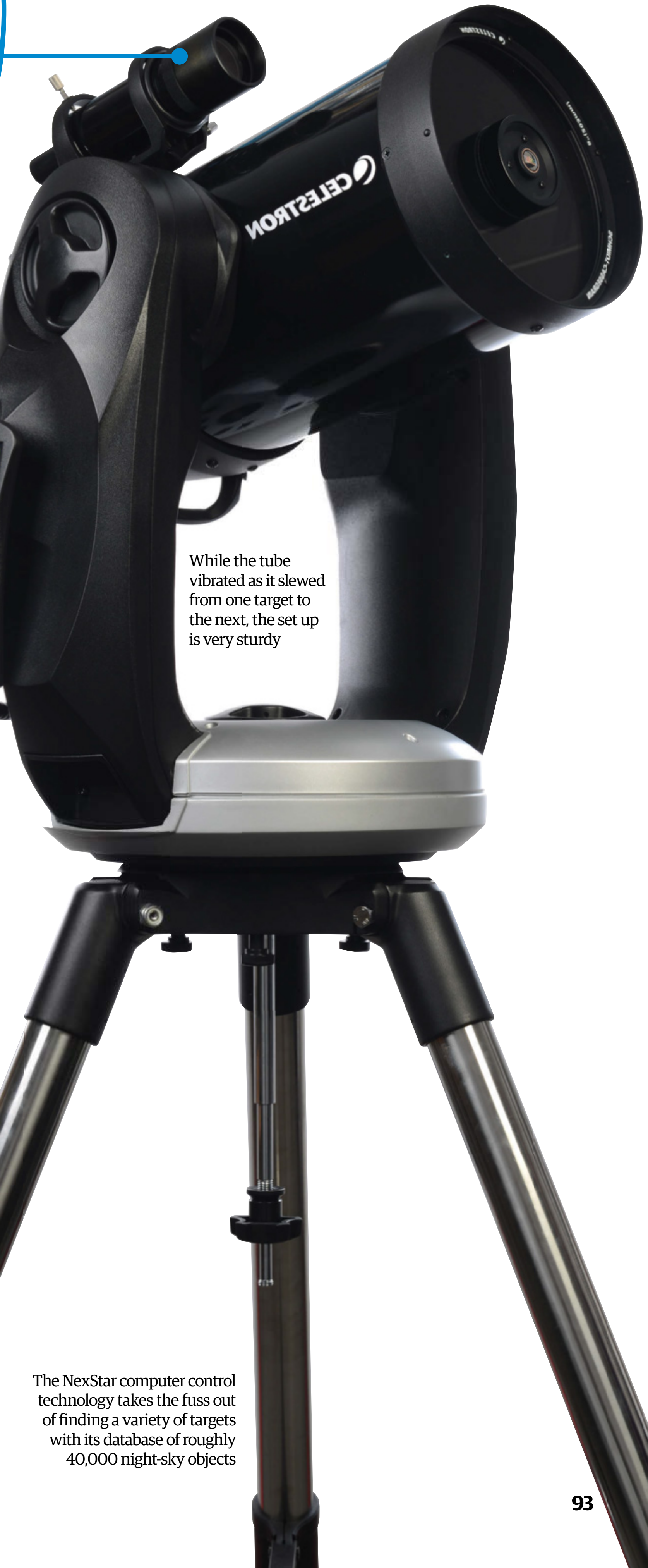
Once set up, the telescope operates relatively flawlessly and, on the whole, is incredibly easy to use. Using the NexStar hand control we instructed the CPC 800 to slew to spiral galaxy M81, also known as Bode's Galaxy, in the constellation of Ursa Major. The telescope's motors are impressively quiet and we didn't notice too much shaking of the tripod as the fork mount turned the tube towards M81. The telescope is supplied with a 40mm eyepiece, which is of beautiful quality and supplies a magnification of 51x. In order to view a selection of targets, you will need to accessorise the CPC 800 with eyepieces that supply low, medium and high power.

Plugging the supplied eyepiece into the holder, we got an impressively clear view of this 12-million-light-year spiral, with the CPC 800 picking it out as a small oval. Bringing the view into focus, the focus knob isn't as smooth as we would have liked but it did the job nonetheless. We waited for the Pinwheel Galaxy, also known as M101, to become visible later on into the early hours of the morning. We were not disappointed with the view of this stunning face-on spiral.

The StarBright XLT coating provides bright, clear views of a variety of targets, making anything from planetary to deep-sky objects a joy to observe. With its database of roughly 40,000 objects, observers will find that they can spend more time observing rather than finding objects, something that's useful when clouds threaten to roll in and spoil an observing session.

It wouldn't be an observing session without locating other members of our Solar System and, indeed, Jupiter was a stunning sight through the CPC 800 in the small hours of the morning. Using the 40mm eyepiece, the gas giant appeared as a small but crystal clear disc with the Galilean moons - Io, Europa, Ganymede and Callisto - showing up as small, pinpoints of light. Allowing our eyes to adjust to the view of the planetary king, we could make out its atmospheric bands. The star diagonal is well-orientated, which allows comfortable viewing for long periods of time.

While the Celestron CPC 800 will make a dent in the savings of many, we have to say that - given the telescope's build, general operation and the state-of-the-art technology it offers - it's worth it, especially if you're looking to replace a basic scope. The CPC 800 gets a massive thumbs up from us! ⬢



While the tube vibrated as it slewed from one target to the next, the set up is very sturdy

The NexStar computer control technology takes the fuss out of finding a variety of targets with its database of roughly 40,000 night-sky objects

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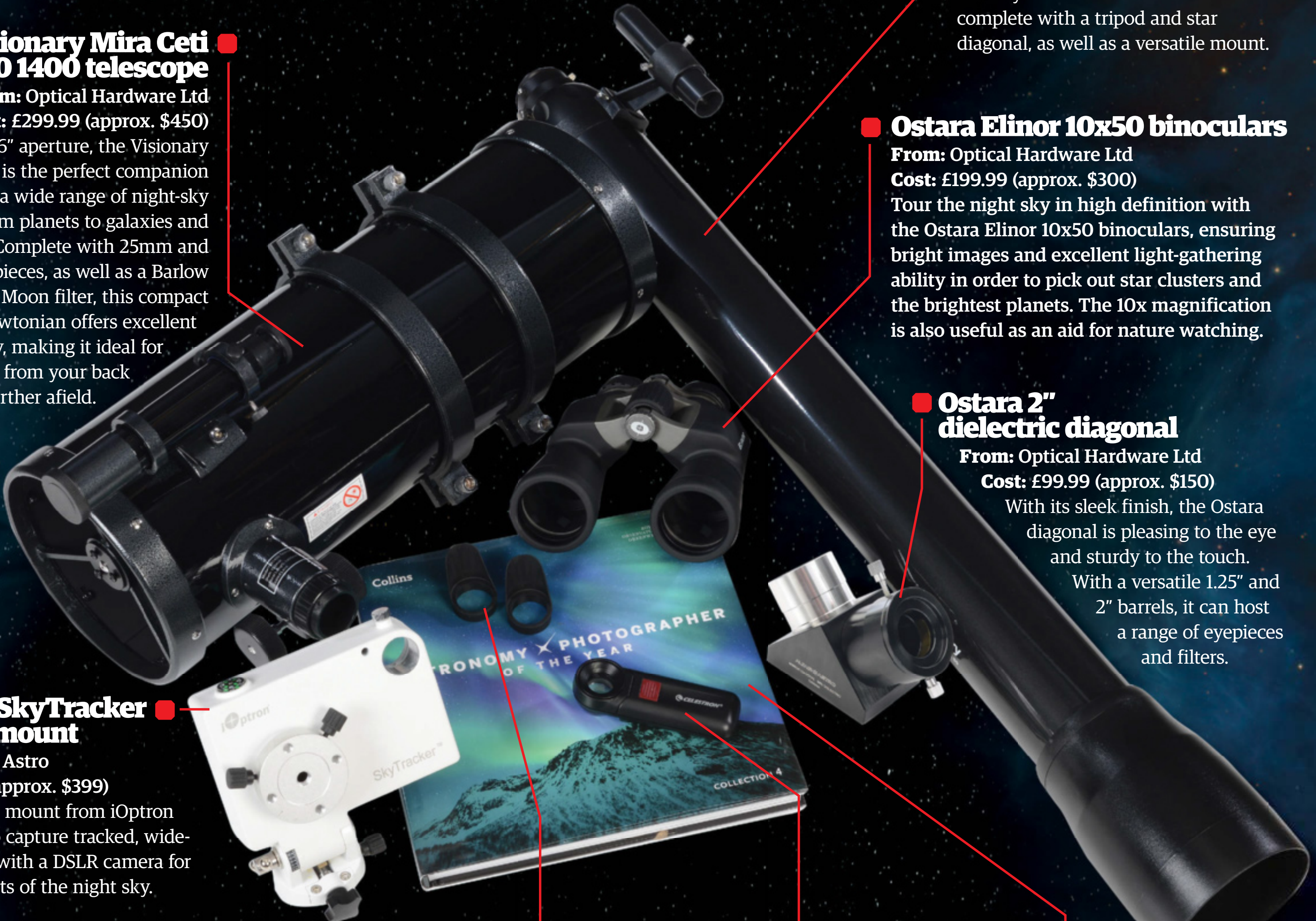

Visionary Mira Ceti 150 1400 telescope

From: Optical Hardware Ltd
Cost: £299.99 (approx. $450)

With its 6" aperture, the Visionary Mira Ceti is the perfect companion to observe a wide range of night-sky targets, from planets to galaxies and nebulae. Complete with 25mm and 6.5mm eyepieces, as well as a Barlow lens and a Moon filter, this compact and light Newtonian offers excellent portability, making it ideal for observing from your back garden or further afield.

Visionary STARLA 80

From: Optical Hardware Ltd
Cost: £199.99 (approx. $300)

Complete with 10mm and 25mm Plössl eyepieces, the Visionary STARLA 80 refractor telescope is the ideal companion for touring the night sky. It's easy to assemble and also comes complete with a tripod and star diagonal, as well as a versatile mount.

Ostara Elinor 10x50 binoculars

From: Optical Hardware Ltd
Cost: £199.99 (approx. $300)

Tour the night sky in high definition with the Ostara Elinor 10x50 binoculars, ensuring bright images and excellent light-gathering ability in order to pick out star clusters and the brightest planets. The 10x magnification is also useful as an aid for nature watching.

Ostara 2" dielectric diagonal

From: Optical Hardware Ltd
Cost: £99.99 (approx. $150)

With its sleek finish, the Ostara diagonal is pleasing to the eye and sturdy to the touch. With a versatile 1.25" and 2" barrels, it can host a range of eyepieces and filters.

iOptron SkyTracker camera mount

From: Altair Astro
Cost: £379 (approx. $399)

This tracking mount from iOptron allows you to capture tracked, wide-field images with a DSLR camera for stunning shots of the night sky.

To be in with a chance of winning, all you have to do is answer this question:

In which year did NASA's Curiosity rover touch down on the surface of the Red Planet?

A: 2010

B: 2012

C: 2015

Field Optics Research Eyeshield

From: Optical Hardware Ltd
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Excellent for use with binoculars or a telescope, the Eyeshield - made using flexible moulded rubber - fits comfortably around the eyes to block out any distracting light and wind, giving complete darkness.

Celestron 10x illuminated magnifier

From: David Hinds Ltd
Cost: £37 (approx. $55)

The Celestron 10x illuminated magnifier is useful whether you enjoy studying stamps, coins, plants, rocks or insects. This device is particularly handy for quality control of telescopes and binoculars and for viewing sky maps.

Astronomy Photographer Of The Year: Collection 4

From: Harper Collins
Cost: £25 (approx. $38)

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Astronomy kit reviews

Stargazing gear, accessories and books for astronomers and space fans alike

Binoculars

Oregon Observation 15x70

Cost: £99 (approx. $140)

From: Opticron

Budding astronomers are often recommended to start out with a good quality pair of 10x50 binoculars when they make their first tentative steps in exploring the night sky. However, we think that the Oregon Observation 15x70s will offer more bang for your buck. Our first impressions of the Oregon Observation 15x70s were favourable when we put them to work - especially for the price. The rubber casing protects the 15x70s' optical system and makes them easy to hold.

Personally, our arms began to shake after holding them up for about three minutes, so for a steadier view we attached them to a tripod - something that is fairly easy to do thanks to their versatile build. The 70mm objective lenses are multicoated and, combined with BAK4 Porro prisms, the optical system provided pleasing views of craters on the lunar surface when we turned them skyward. The eye relief is exquisite, and there was only a hint of colour fringing along the Moon's limb and brighter stars. All in all, though, these binoculars are a worthy purchase.

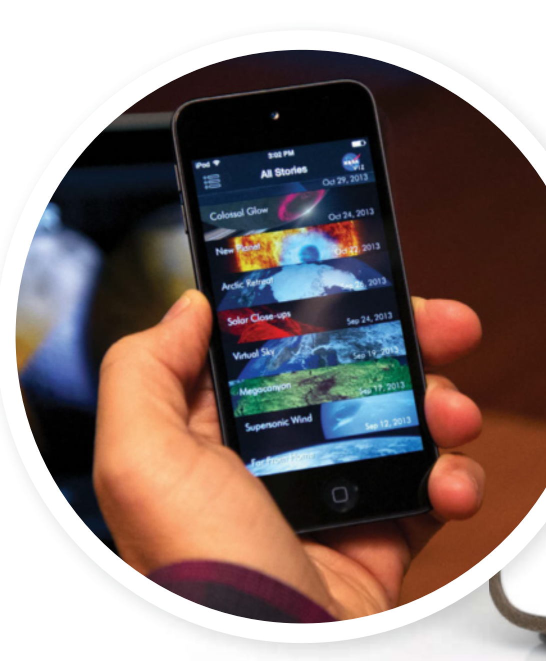
Sky Tracker

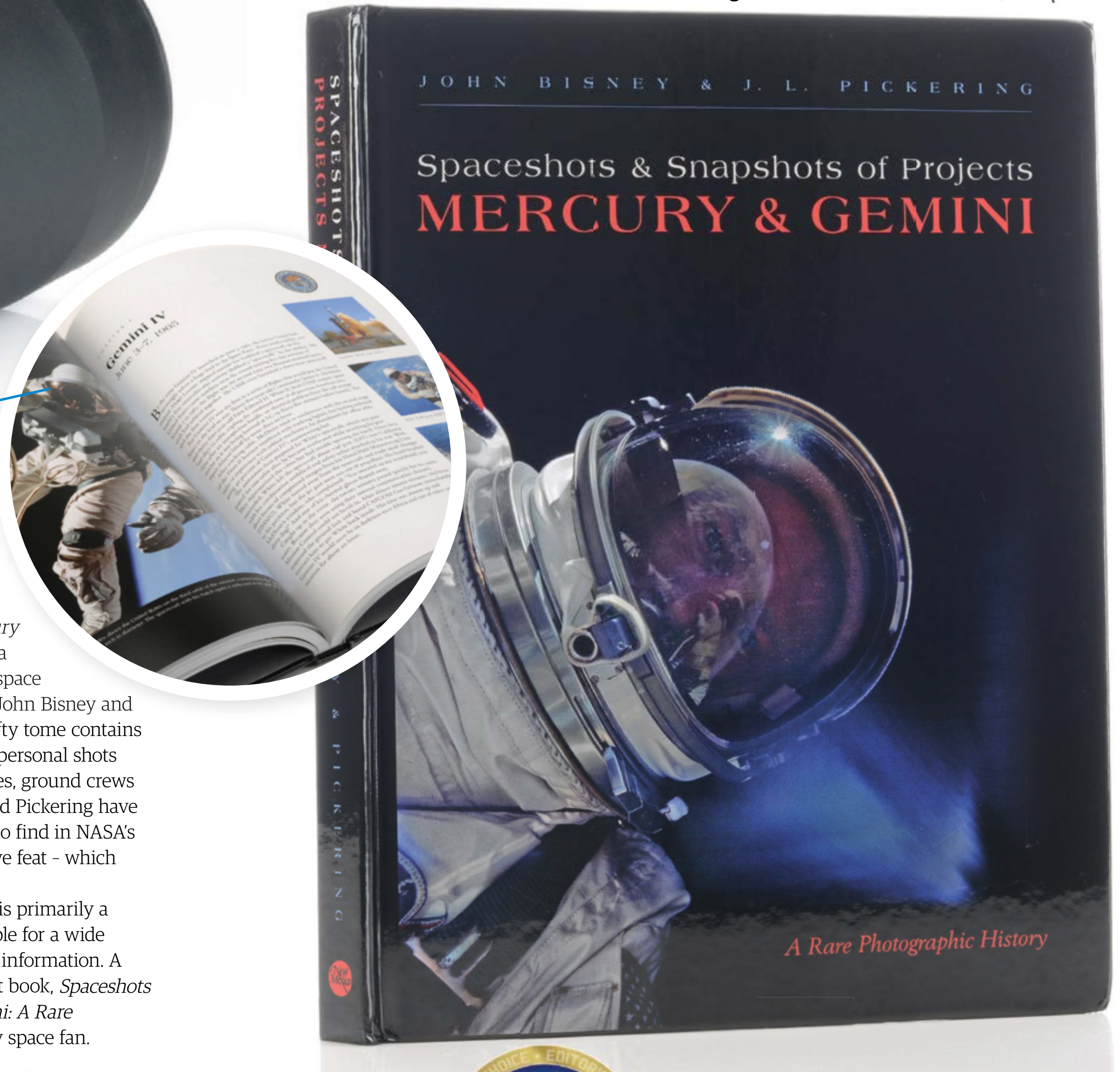
iOptron SkyTracker V2 DSLR Camera Mount with Polar Scope

Cost: £299 / $399

From: Altair Astro

If you're an astrophotographer that gravitates towards a DSLR camera for wide-angle night sky shots rather than a CMOS or CCD for deep sky and planetary viewing, then the iOptron SkyTracker is a very rewarding purchase for capturing the dusty trail of the Milky Way and other large field shots - without having to worry about the Earth's rotation blurring imagery of the heavens. This SkyTracker can be used in both the Northern and Southern Hemispheres. The SkyTracker can either be powered by four AA batteries - for nonrestrictive use - or via the power connector. In the field, the SkyTracker held a Canon EOS 70D with no problems at all and we found the integrated compass to be extremely useful. Sadly, the same couldn't be said for the in-built spirit level, which failed to tell us if the system was level before we began imaging. Once set up, we were able to achieve very good image results, with the Milky Way's stars pinpointed with ease as the SkyTracker worked against the rotation of our planet. The perfect companion for anyone in need of assistance with nightscape imaging.

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June 3-7, 1965
JOHN BISNEY & J. L. PICKERING
Spaceshots & Snapshots of Projects
MERCURY & GEMINI
A Rare Photographic History
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Book

Spaceshots & Snapshots Of Projects Mercury & Gemini: A Rare Photographic History

Cost: £41.95 / $45

From: University of New Mexico Press

Spaceshots & Snapshots Of Projects Mercury & Gemini: A Rare Photographic History is a rich depiction of America's early manned space programmes. Written by space journalist, John Bisney and spaceflight historian J L Pickering, this hefty tome contains both formal and frank photos, along with personal shots that show the astronauts with their families, ground crews and launch teams. Impressively, Bisney and Pickering have obtained rare images that you're unlikely to find in NASA's archives – which we admit, is an impressive feat – which seem to uncover lost bits of history.

Given that Bisney and Pickering's work is primarily a photographic book, it's a casual read suitable for a wide audience whilst still providing a wealth of information. A well-made and extremely well thought out book, *Spaceshots & Snapshots Of Projects Mercury & Gemini: A Rare Photographic History* is sure to delight any space fan.

(1:55, audio) Jupiter's hot spots, though constantly changing, are governed by an atmospheric wave, as explained in this video.

All About Space
EDITOR'S CHOICE

App

NASA Visualization Explorer

Cost: Free

From: iTunes

With a treasure trove of information, this latest application from NASA is very educational and interactive, providing you with digestible titbits of information so that you don't have to take in too much all at once. Even better, it's entirely free for all iPad and iPhone users, providing you with the perfect companion to learn all about NASA and its missions, cutting-edge research and spacecraft, as well as boasting a wealth of general space-science facts to keep you updated. New stories are posted every week, so it's important that you're hooked up to WiFi or a suitable data connection on your iPhone. We got stuck into the new updated version (1.9.6) of the NASA Visualization Explorer as soon as we downloaded it and found there was no crashing of the movie player (a bug that put off many users of the earlier versions) and this handy app played audio seamlessly. There is always something new to learn, plus stunning illustrations and images along the way, so the NASA Visualization Explorer gets a huge thumbs up from us!

Clyde Tombaugh

The amateur astronomer who discovered Pluto and visited the dwarf planet after his death

Clyde Tombaugh's discovery of Pluto has been honoured many times by the New Horizons mission team

The existence of a planet beyond Neptune had been predicted by prominent American astrologer, Percival Lowell in 1905 but it was never proven in his lifetime. He had aimed a 40-inch reflector telescope at what he believed to be the right section of the sky, but he died in 1916 with his dream of discovering his so-called Planet X sadly unrealised. It was to be his biggest disappointment, yet it was the catalyst for a continued search. And, for amateur astronomer Clyde Tombaugh, Lowell's hunch would yield great results.

Lowell's legacy was the observatory that bore his name and which had been built in 1894 for the purpose of studying Mars. It had come to be looked after by his nephew, Roger Lowell Putnam, who in a twist of fate had been approached by Tombaugh in 1929, seeking feedback on his detailed drawings of Jupiter and Mars. Tombaugh was in his early 20s and he had built his own telescope. With an instant offer of a job, Tombaugh could never have foreseen what his decision to contact astronomers at the Lowell Observatory would lead to.

Tombaugh, who was born in Streator, Illinois and grew up on a farm in Kansas, was tasked with leading the search for Planet X using a device called a blink comparator - a piece of viewing apparatus used to discover the differences between two images of the night sky. By looking for apparent changes in the position of objects, Tombaugh struck upon something extraordinary after ten months of hard work. He noticed a planet-like body on 18 February 1930 and some three weeks later - on 13 March 1930 - Pluto's discovery was announced.

It would prove to be an amazing start to Tombaugh's career but it was not quite a case of him peaking early. Tombaugh continued to work at the Lowell Observatory until 1945 and he took the opportunity from 1932 to 1938 to study for a bachelor's and master's degree in astronomy at the University of Kansas. He was making a long-lasting contribution to the understanding and exploration of space and his discoveries would have ramifications for decades to come.

Certainly, his qualifications stood him in good stead during his time teaching astronomy at New Mexico State University from 1955 until his retirement in 1973, but it was his other discoveries that provided the icing on the cake. He found hundreds of new variable stars and asteroids and also discovered two comets and thousands of new star and galaxy clusters. Fittingly, Asteroid 1604 Tombaugh, which he discovered in 1931, was named after him. And, some others were named after his family.

Indeed, Tombaugh was a family man and when he died on 17 January 1997 at the age of 90, he left behind his wife, Patricia, and his two children, Annette and Alden. Whether fortunate or not, this meant he wasn't around in 2006 when the International Astronomical Union voted to re-classify Pluto as a dwarf planet, following the 2003 discovery of Eris and the observation of other smaller sized bodies in the Kuiper Belt - the circumstellar disc which extends beyond the orbit of Neptune. Quite what he would make of the controversial downsizing of his iconic discovery will therefore never be known, but Tombaugh's story does not stop there.

In that same year, New Horizons was launched from Cape Canaveral to study the Pluto system and, as a secondary mission, the Kuiper belt. And, on the inside of the upper deck of the probe was affixed a small container carrying Tombaugh's ashes.

Last year, as New Horizons made its fly-by of Pluto, the addition allowed Tombaugh to get close, in death, to the planet that defined his working life. And, exactly 110 years on from the date of his birth - the 4 February 1906 - we are sure that Tombaugh would be pleased to be out there in the universe he loved so much. ■

All About Space

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